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## THE ELECTRIC LIGHT

. . AND . .

## STORING OF ELECTRICAL ENERGY

BY

GERALD MOLLOY



ILLUSTRATED



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## THE STORING OF ELECTRICAL ENERGY.

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# THE ELECTRIC LIGHT.

TWO LECTURES

DELIVERED IN THE THEATRE OF THE ROYAL DUBLIN SOCIETY,

*MARCH, 1888.*

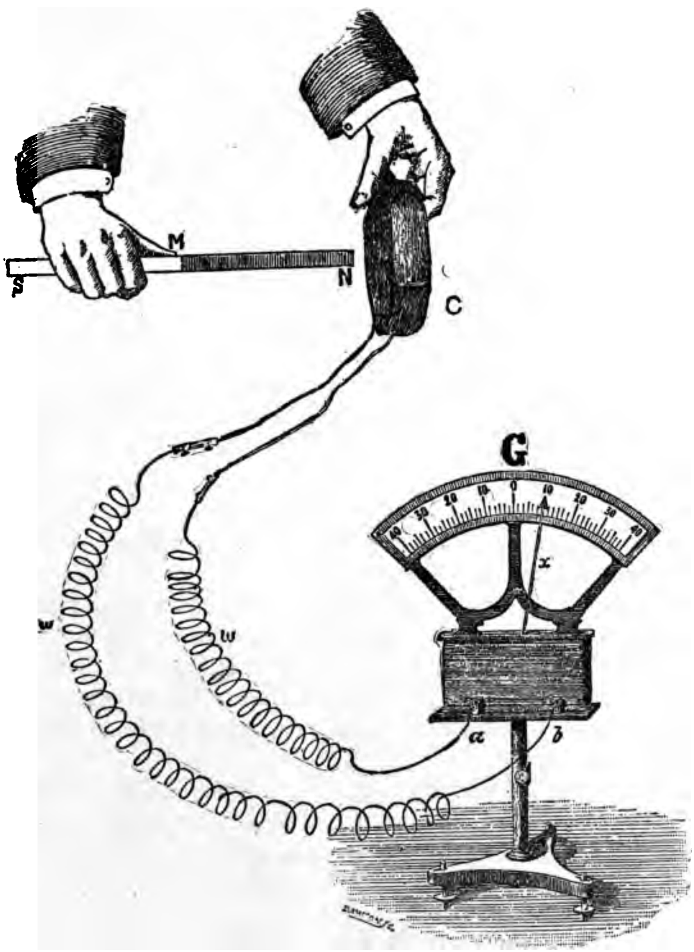
## LECTURE I.

### HOW THE ELECTRIC CURRENT IS PRODUCED.

AN Electric Light installation consists essentially of two parts: one part, in which an electric current is generated; and another, in which the energy of the current is converted into light. The electric current is now almost universally produced, for the purposes of Electric Lighting, by means of a Dynamo-Electric machine, or, as it is more familiarly called, a Dynamo; and the energy of the current is converted into light in some one form or other of the Electric Lamp. I propose, then, in my Lecture to-day, to give you a short account of the Dynamo, tracing the history of its development from its first origin down to its present high degree of perfection; and in my second Lecture, I will deal with the Electric Lamp, and explain, as far as I can, the process by which the electric current is made to yield us the electric light.

**Faraday's Discovery.**—In the month of November, 1831, Faraday read a paper before the Royal Society of London, in which he announced, for the first time, a discovery which will be memorable forever in the annals of science. He showed that when a closed circuit, that is to say, a conductor the ends of which are connected together electrically, is moved in the presence of a magnet, a current of electricity is developed in the circuit, during the time of its motion. It would detain us too long to repeat all the experiments by which this discovery was established, but I can give you a general idea of the nature of these experiments in a few words.

I have got here, in my left hand, a coil of copper wire, which is covered with an insulating material, so that a current of electricity, developed in the wire, may not pass across from spiral to spiral, but must travel all round each spiral before passing to the next. In my




CURRENT OF ELECTRICITY PRODUCED BY THE MOTION OF A COIL OF WIRE IN PRESENCE OF A MAGNET.

M Bar Magnet.
C Coil of Copper Wire.
*w w* Wires conveying the Current.

G Sensitive Galvanometer.
*a b* Binding Screws of Galvanometer.
*x* Index of Galvanometer.

right hand I hold an ordinary bar magnet. Now what Faraday showed was simply this: that if the ends of the copper wire are connected together, forming what is called a closed circuit, a current of electricity will be developed in the coil, when it is moved in the presence of the magnet.

To demonstrate the presence of this electric current, I have placed on the table a very delicate galvanometer, made by M. Bourbouze, of Paris. I need not tell you that a galvanometer is an instrument whose function it is to reveal the presence of a current of electricity, and at the same time to indicate the direction in which the current flows. This particular instrument before you is provided with a long index, which is visible I hope to all present, and which now points to zero on the scale: but when a current of electricity flows through the apparatus, the index will be deflected from its position of rest, and will swing to the right or to the left, according to the direction in which the current is flowing.

My assistant will now connect the ends of the coil with the binding screws of the galvanometer, by means of light flexible wires. In so doing, he practically makes a closed circuit, of which the coil of copper wire is one part and the galvanometer another: and now, if an electric current is developed in the coil, it must flow through the galvanometer, and its presence will be revealed by the deflection of the index.

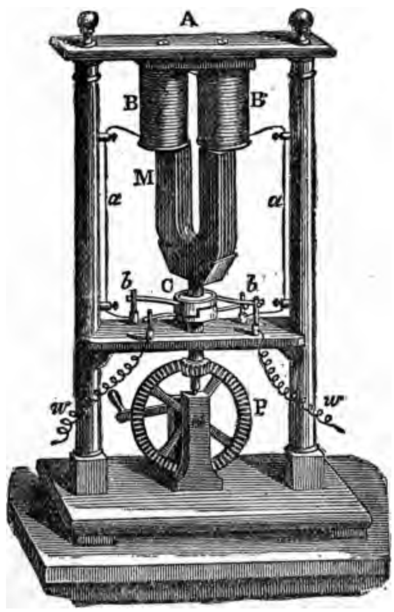
With this apparatus I can reproduce in substance the experiments of Faraday, so as to make the results apparent to every one present. I move the coil towards the north pole of the magnet, and the index of the galvanometer swings to the right, showing that a current has passed. But observe, the index, after swinging back and forward a few times, comes to rest again, at zero; from which we may infer that, when the coil and the magnet are both at rest, no matter how close they may be, no current is produced. Next, I move the coil away from the north pole, and again the index is deflected; but this time it swings to the left, showing that the new current developed is opposite in direction to the former.

I repeat these experiments with a south pole. When I move the coil towards the south pole, the index swings to the left; when I move it away, the index swings to the right. Thus we learn that the current produced by the action of a south pole is, in each case, opposite in direction to that produced by a north pole.

Pursuing these experiments, Faraday further showed that the current is greatly intensified, if the copper wire is wound round a bar of soft iron. He also showed that the current developed is stronger, in proportion as the magnet employed is more powerful, and in proportion as the motion is more swift. And lastly, he showed that the current is equally produced, in all cases, whether the magnet is at rest

and the coil is moved, as was the case in our experiments, or the coil is at rest and the magnet moved. These are the main facts which Faraday established by experiments carried out in the Royal Institution of London, just fifty-seven years ago; and upon the basis of these facts, it is simply true to say, have been built up all the Dynamo-Electric machines that are now at work in the world.

Faraday was himself fully conscious of the importance of the discovery he had made; and he believed it to be capable of many useful applications. But these applications he left to others to seek out; and having handed over his discovery to the world, with all its potency of




PIXII'S MACHINE, 1832.

B B Bobbins of Wire.
M Horse-shoe Magnet.
P Wheel and Pinion to drive round the Magnet.
*a a* Wires to carry the Currents from the Bobbins to the contact pieces *b b*.
C Commutator to collect the Currents and transmit them to the Wires *w w*.

future development, as an inheritance forever, he turned his attention to new fields of research, in the hope of discovering new truths, and enlarging still more the bounds of human knowledge.

**First Machines founded on Faraday's Discovery.**—The first practical application of Faraday's discovery to the construction of a machine for generating an electric current was made in 1832, by Pixii, a manufacturer of philosophical instruments in Paris. You will easily understand the construction of his machine from the diagram before you. Two bobbins of wire, B B, each having within it a core of soft iron, are mounted in a fixed position on the solid frame A. Immediately below the bobbins is a horse-shoe magnet M, so adjusted that it can

be made to rotate rapidly by means of the wheel and pinion P. As the magnet rotates, its poles pass alternately close before the face of each bobbin; currents of electricity are thus generated in the bobbins, and these currents are carried, by the wires *a a*, to the spring contacts *b b*, from which they pass to the commutator C. From the commutator the currents are transmitted to the wires *w w*, by which they may be conveyed to any external circuit, for practical use.

It was soon found, however, that it was more convenient to make the bobbins of wire revolve before the poles of the magnet, than to


CLARKE'S MACHINE, 1836.

M Horse-shoe Magnet.
BB Bobbins of Wire.
W Wheel to drive the Bobbins.
C Commutator.
*s s* Springs to convey the Currents from the Commutator to the external Circuit, through the Wires *w w*.

make the poles of the magnet revolve before the bobbins. This modification was first introduced by Saxton, in the year 1833, and was afterwards adopted by Clarke, whose machine, first brought out in 1836, has survived, in one form or another, down to the present day. The diagram on the wall represents one of the earliest forms of Clarke's machine: M is the horse-shoe magnet, B B are the bobbins of wire, and W is the wheel by means of which the bobbins are made to rotate before the poles of the magnet. The currents of electricity developed in the bobbins pass to the commutator C, which is fixed on the axis of rotation; and from the commutator they are conveyed by

the springs *s s*, which press against the commutator as it revolves, to the wires *w w*, by which they pass into the external circuit.

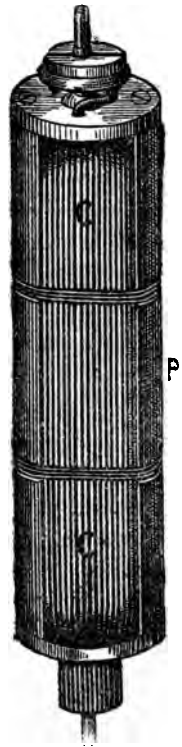
Clarke's machine has been found very convenient for medical purposes, and it is in general use, even at the present day, amongst medical men, in a great variety of forms. The specimen here on the table, made by Gaiffe of Paris, is one of the most recent: it is firmly fixed in a rectangular box to make it more portable, and it is provided with a variety of appliances by which the currents developed may be conveyed to various parts of the human body.

I should tell you that, in all these machines, the electric currents developed in the coils of wire flow in one direction during one half of each revolution, and in the opposite direction during the other half revolution. You will remember that, in repeating Faraday's experiments, a little time ago, I showed you that when a coil approached a magnetic pole, the current flowed in one direction, and when the coil receded from the pole, the current flowed in the opposite direction. I showed you also that the currents developed by motion to or from a north pole are always opposite to the currents developed by motion to or from a south pole. It is a consequence of these laws that, in the machines before us, the currents generated in each half revolution of the bobbins are in opposite directions. Hence, if we connect the ends of the wire coming from the bobbins directly with an external circuit, the currents will flow alternately in opposite directions in the external circuit. But an ingenious contrivance, called a commutator, has been devised, by means of which the currents, though flowing alternately in opposite direction in the bobbins, are all sent into the external circuit in the same direction.

I need not trouble you with the mechanical details of the commutator. Enough it is to know that we have two types of machine. In one type, where the commutator is not employed, the currents in the external circuit flow alternately in opposite directions; in the other, where the commutator is introduced, the currents in the external circuit flow all in the same direction. The one type is called the alternate current machine; the other is called the continuous current machine. Both types are in general use: and both, I may say by anticipation, are at the present moment employed for producing the Electric Light.

**Siemens' Armature.**—In the progress of scientific discovery there are periods of activity and periods of repose. The production of Clarke's machine, in 1836, was followed by a long period of repose; for no further improvement was made from that date until 1857, when Dr. Werner Siemens, of Berlin, introduced a new method of winding the bobbin of wire, or armature, as it is called. You will have observed that, in the machines I have aready described, only one face of each bobbin comes close to the poles of the magnet; the other face is

always turned away, and therefore the influence of the magnet upon it must be comparatively feeble. Siemens conceived the idea of so constructing his bobbin that each face of the coil might come close to the magnet poles, and the inductive effect of the magnet be thereby greatly increased.



SIEMENS' ARMATURE, 1857.

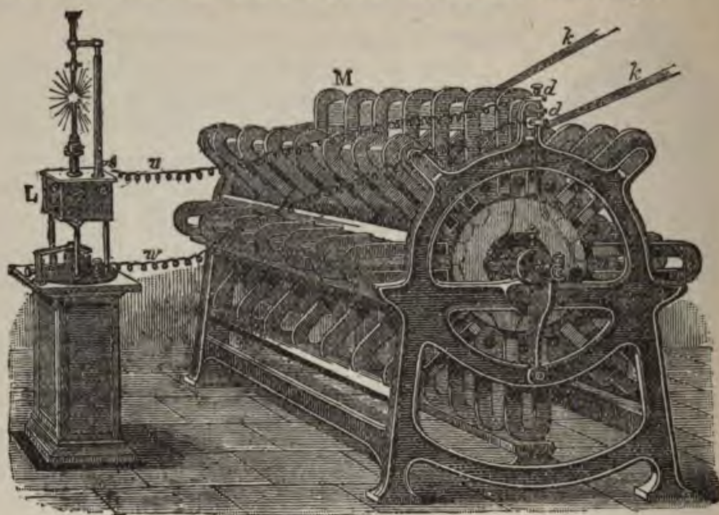
Here is one of his bobbins in the form in which they were first brought out; and here is the machine in which it works. The bobbin is prepared by taking a cylindrical bar of soft iron, and cutting a deep wide groove on both sides all along its length. The insulated copper wire is then wound, in this groove, like thread upon a shuttle. In the machine, a number of horse-shoe magnets are mounted on a stand, with all the north poles on one side, and all the south poles on the other. These poles are so shaped as to allow the cylindrical armature to fit between them, with just room enough to rotate freely.* When the armature is put in rotation each face of the coil comes alternately, first opposite one row of poles, and then opposite the other, and inductive action takes place under the most favorable conditions.

**First Machines for Production of the Electric Light.**—Soon after the introduction of Siemens' armature, practical men began to realize that the power of these machines might be increased almost indefinitely. It was only necessary, following out the principles laid down by Faraday, to get larger magnets and a greater number of them, to coil more wire on the armature, and to drive it at a greater speed, and an electric current might be generated far surpassing any that had ever been obtained from batteries. It was suggested, too, that such currents might be used with great advantage to produce the electric light for the illumination of Lighthouses.

This idea was taken up about the same time in England and in France, and was soon carried to a successful issue. A very powerful machine, constructed by the Alliance Company, in France, and driven by a steam-engine, was established at the Lighthouse of Cape La Hève, near Havre, about the year 1863, and used from that time forward for the production of the Electric Light. The construction of the Alliance machine may be easily understood from the diagram before you. You see here eight rows of magnets M M, mounted on a massive frame, with seven magnets in each row, or fifty-six magnets in

*For a figure of Siemens' machine, see page 21.

all. Between the poles of these magnets a large Siemens' armature is driven round by the belt *k k*; the currents are collected at the binding screws, *d d*, and are carried by the wires *w w* to the lamp L.




MACHINE OF THE ALLIANCE COMPANY, 1863.

M M Horse-shoe Permanent Magnets. | *w w* Wires for conveying the Current from Machine to Lamp L.
*k k* Belt for driving Armature.

A machine quite similar to this was constructed, in England, by Holmes, who had previously been in the service of the Alliance Company, and was mounted on the sixth of June, 1862, at the South Foreland Lighthouse, where it continued to be worked very successfully for many years. This machine, at the South Foreland, is particularly interesting, because it was set up under the direction of Faraday himself, who, at the time, was scientific adviser to the Elder Brethren of Trinity House, and who thus had the satisfaction of seeing, after the lapse of thirty years from the date of his great discovery, this offspring of his own genius already arrived at maturity, and entering on a career of usefulness which is likely to last as long as the world itself.

**First Machine with Electro-magnet.**—But these machines, though successful for their time, were bulky and cumbrous; and hardly had they been seen in action, when the idea was suggested that a great saving might be effected, in size and weight, by the employment of electro-magnets, instead of permanent steel magnets. An electro-magnet, as I dare say you know, consists of a bar, or plate, of very soft iron, round which is coiled an insulated copper wire. Here is one, bent into a horse-shoe shape, and suspended from this tripod stand. It shows no sensible signs of magnetic power, when I present to it a tray of iron nails. But the moment I turn on an electric current, and

make it flow round the coil of copper wire, you see how the nails are suddenly attracted, and held suspended in the air, the magnetic power passing through the mass, so that they stand out in a cluster round the poles of the magnet. Again, when I shut off the current, the magnetism of the soft iron bar is lost as suddenly as it was acquired, and the nails fall down, in a heap, to the ground.

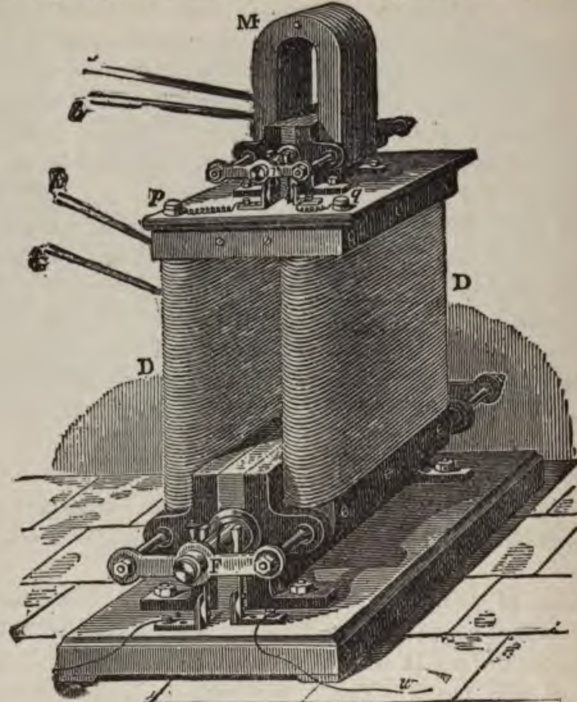
What you have chiefly to observe in this experiment is first, that an electro-magnet is far more powerful than a permanent steel magnet, of equal weight; and secondly, that it can acquire its magnetic power in a moment, and lose it in a moment. But I would ask you also to notice an incidental circumstance of the experiment, which though apparently trivial, has a singularly interesting application, as you will see by-and-by, in the Dynamo-Electric machine.

Observe that, although the great mass of nails has fallen down from the poles of the electro-magnet, there are one or two of the smaller nails still feebly clinging to it. To satisfy you that this is not a mere accident, I repeat the experiment again and again: each time, when the current is shut off, two or three small nails remain attached to the poles of the magnet. From this we may infer that, although the iron bar loses its magnetism, when the current ceases to pass, it does not lose it altogether; some faint traces still remain. This is called residual magnetism: and I ask you now to take a note of it, because you will see, a little later on, what an important part this residual magnetism will be called upon to play, in the development of our machine.

The idea of using an electro-magnet in the construction of a Dynamo was first carried out by Wilde of Manchester, in 1867. From the diagram before us, it will be seen at once that Wilde's machine consisted of two parts. The upper part is simply a machine of Siemens, such as I have just described to you. Here is a row of permanent horse-shoe magnets M, with two oblong masses of soft iron as pole pieces. Between these poles pieces a Siemens' aramature, one end of which is seen at *r*, is made to rotate by the belt *b b*.

The electric current generated in the armature, instead of being carried off to the external circuit, is conveyed from the binding screws *p q*, round the coils of a large electro-magnet D D, imparting to it a magnetic power far surpassing that of the permanent magnets above. Between the pole pieces of this electro-magnet, a second Siemens' armature, very much larger than the first, one end of which appears at R, is driven round by the belt *k k*, which is worked by a steam engine not shown in the sketch; and an electric current of great power is produced, which passes to the external circuit by the wires *w w*. This machine was first exhibited before the Royal Society of London in March, 1867, and afterwards at the Paris Exhibition in the summer of the same year, where it attracted very general attention.

**A new Principle discovered.**—But Wilde's machine was hardly finished when it was superseded by a new discovery, made about the same time by Dr. Werner Siemens, of Berlin, and Professor Wheatstone, of London. The practical result of this discovery was to show that the upper part of Wilde's machine was unnecessary; inasmuch as the current required to excite the electro-magnet can be obtained from




WILDE'S MACHINE, 1867.

M Row of Permanent Magnets.
*b b* Belt to drive Armature of Small Machine.
D D Large Electro-magnet.
*k k* Belt to drive Armature of Large Machine.
*w w* Wires to carry Current to external Circuit.

the action of the electro-magnet itself. At first sight, this statement looks like a paradox: we are to produce a current by means of an electro-magnet, and we are to make the electro-magnet by means of the current so produced. But the explanation is to be found in the phenomenon of residual magnetism, to which I called your attention a little time ago.

An electro-magnet, once excited, retains, for a considerable time, some faint traces of magnetism. Hence, if we suppose the upper part of Wilde's machine to be removed, and the armature in the lower part to be put in rotation, it would rotate, in fact, between the poles of a feeble electro-magnet, and accordingly a feeble current of electricity would be developed in the coils of the armature. Now this current

may be conveyed round the coils of the electro-magnet, so as to increase its magnetic power, and thereby to increase the strength of the current developed in the armature. The same arrangement will convey this stronger current round the electro-magnet, thereby increasing still more its magnetic power, and increasing, at the same time, the strength of the current developed. And so the process may be continued, the power of the magnet and the strength of the current being rapidly exalted, until a certain maximum is attained at which the current is able to maintain the magnet at a high degree of magnetic intensity, and to do work in the external circuit as well.

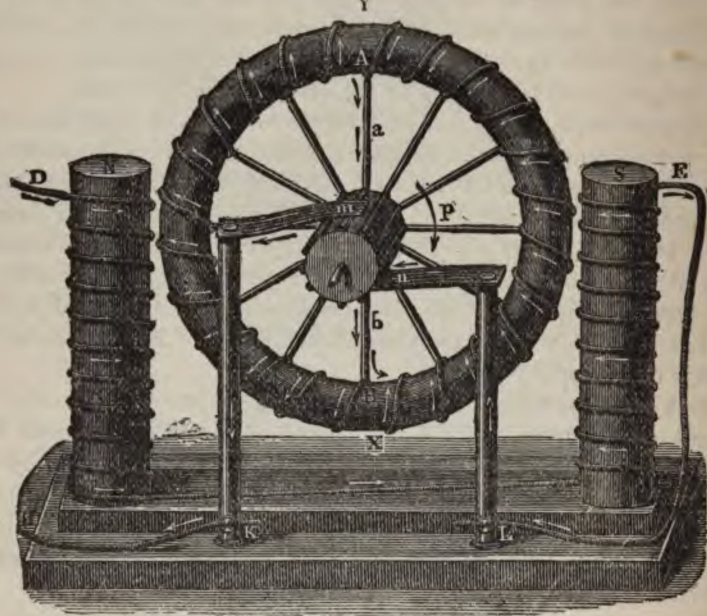
This principle, which was destined to bring about a revolution in the construction of Dynamo-Electric machines, was brought under the notice of the Academy of Science of Berlin by Dr. Werner Siemens, in the month of January, 1867, and in the following month of February it was brought before the Royal Society of London, by Professor Wheatstone, who had discovered it independently for himself. It soon received practical application, in a machine constructed by Mr. Ladd of London, which was exhibited at the Paris Exhibition in the summer of the same year.

But Ladd's machine, though it attracted a great deal of notice on account of the novel principle it embodied, never came much into practical use. It was followed, however, after a brief interval, by two machines, founded on the same principle, which may be said to mark an epoch in the history of our subject; I mean Gramme's machine, which was brought out in 1871, and Siemens' machine, which appeared in 1873.

It is worth while to dwell for a few moments on the construction of these two machines; for practically they furnish the types on which almost all the various forms of Dynamo machines have been since constructed. They differ from one another, chiefly in the way in which the insulated copper wire is wound on the armature, or rotating bobbin; Gramme having invented a new form of armature, and a new mode of winding the wire, while Siemens adopted a modification of the armature previously invented by himself, the construction of which I have already explained to you.

**The Gramme Machine.**—I think I can best give you a clear idea of the principle of the Gramme machine if I show you, in the first instance, not the machine itself, but an ideal skeleton, which exhibits all its essential parts, in their simplest form. In the diagram before you A B is a ring of soft iron, round which is coiled an insulated copper wire, with its ends connected together so as to form a continuous circuit. This ring can be made to rotate on its axis between the poles N S of an electro-magnet. How the magnetism of the electro-magnet is established and maintained I will explain by-and-by: for the present I simply assume that N and S are two magnetic poles, north and south respectively.

Now let the ring revolve in the direction of the arrow $p$. It may be shown, according to the principles established by Faraday, that as each spiral of the coil moves onward from X towards N a current of electricity is generated, which flows in the direction marked by the arrows: and again, as each spiral moves away from N towards Y, a current of electricity is also developed, and in the same direction.




IDEAL SKELETON OF GRAMME'S MACHINE.

| | | |
|---|---|---|
| A B | Ring of Soft Iron. | The Arrow $p$ shows the Direction of Rotation. |
| N S | Poles of Electro-magnet. | The other Arrows show the Direction of the Currents. |
| $m$ $n$ | Copper Springs to collect the Current. | |

Thus while the ring is revolving, as supposed, a force is developed which tends to make an electric current flow in that half of the ring which, for the time being, is on your left hand, from X upwards to Y. Similarly it may be shown that a force is developed in that half of the ring which, for the time being, is on your right hand, and this current too is from X upwards towards Y.

It is usual to conceive the action of these two forces as producing, on both sides of the ring, a gradual rise of what is called Potential between the spiral which, at any moment, is passing the point X, and the spiral which, at the same moment, is passing the point Y. Thus a Difference of Potential is maintained between the spiral which, for the time being, is at X, and the spiral which, for the time being, is at Y, the former being always at the lowest Potential, and the latter at the highest, of the whole coil. Now a Difference of Potential as regards

electricity is like a difference of level as regards water. Water always tends to flow from a higher level to a lower level, and, when it flows, it is able to do work: so, too, electricity always tends to flow from a point of higher Potential to a point of lower Potential, and as it flows it is able to do work. Hence if a conductor of electricity be introduced between the spiral which for the time being is passing Y, and the spiral which for the time being is passing X, a current of electricity will flow through such a conductor, and may be used to do work as it flows.

But how are we to introduce such a conductor, seeing that the spirals are all in motion, and that they are covered with an insulating material? The answer to this question leads us to one of the most ingenious devices of the Gramme machine. You will observe that every second spiral of the coil communicates with the axis of the ring, by means of a radius which is made of a good conducting material, and which connects the wire with a narrow copper plate, set edgeways in the circumference of the axis. Thus each of these little copper plates is, at every moment, in the same electrical condition as the corresponding spiral of the ring.

Now look at the two brass pillars in front of the ring. Each has attached to it a light copper spring. The one above, marked *m*, presses gently on the copper plate which is connected, through the radius *a*, with the spiral at the moment passing the point Y; the one below, marked *n*, is similarly pressing on the copper plate which is connected, through the radius *b*, with the spiral at the moment passing the point X. Hence the copper spring *m*, and the binding screw K connected with it, are always at the higher potential belonging to the spiral at Y; and similarly the spring *n* and the binding screw L are always at the lower potential belonging to the spiral at X. If, then, we connect K and L by means of a wire, a current will flow through the wire, and we can use it to produce the Electric Light, or to do any other kind of work.

Let us now come back to the Electro-magnet. I have hitherto assumed that it has magnetic power, all through the process I have described: it remains for me to show you how that magnetic power is imparted to it. At the outset, as I have already explained, the electro-magnet has some residual magnetism, which though feeble produces its due effect, and develops a feeble electric current in the rotating ring. This current is carried off to the external curcuit by the wire H, and coming back at D, is carried round the electro-magnet, so as to make N a stronger north pole, and S a stronger south pole, than they were before. The stronger magnetism develops a stronger current, and this stronger current, carried round the wire coils, increases still more the strength of the magnet; and so the strength of each is alternately increased, until, in less time than it takes to tell it, the maximumpower of the machine is reached.

Gramme's machine, and has done good service in its time: it is called the Type d'Atelier, or Workshop Type. These two massive horizontal bars, one above and one below, are the electro-magnets. The coils of the magnets are so wound that the poles are in the centre; and you can see the great pole pieces, one above and one below, arched as I have described them, and encircling a large part of the ring armature, which has just room to revolve between them. The armature itself is partly concealed from view; but enough is exposed to make it plainly visible, as I turn it slowly round between the poles of the magnet. On the axis of the armature you can see, too, the narrow edges of the commutator plates, which are here sixty in number. And lastly, here are the brushes, pressing lightly on opposite sides of the commutator, which collect the current and make it available for use in the external circuit.

This machine of Gramme's is curiously associated with the memory of the first Napoleon. On the tenth of November, 1801, or, as it was then called, the nineteenth Brumaire of the year X, a paper was read before the Institute of France, by the celebrated Volta. The subject of the paper was the well-known battery which he had just invented, and which has since been called, after him, the Voltaic Battery. The First Consul was present at the meeting; and being greatly struck by the prospects which the paper seemed to unfold, he offered a prize of 60,000 francs, to be open to the scientific men of all countries, and to be called the Volta Prize, for the best practical applications of the power of electricity.

This Prize was renewed by Napoleon the Third, by whom it was awarded three times, the amount, however, being reduced to 50,000 francs. It was again awarded under the Republic, in 1871, almost immediately after the close of the Franco-Prussian war. The last competition for it was opened in July, 1882, and closed in July, 1887; and on this occasion the Prize was awarded to Zénobie Théophile Gramme, for the invention of his Dynamo-Electric machines.

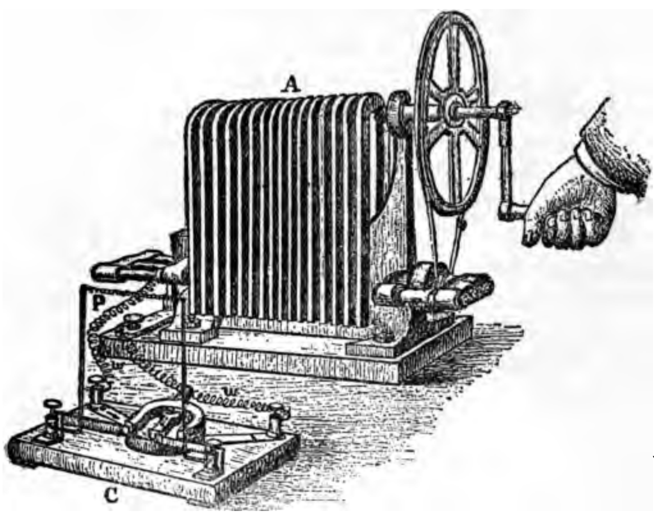
It is interesting to know that, even so late as 1862, M. Gramme was a working carpenter in the employment of Rumkorff, a well-known maker of philosophical apparatus in Paris. He had no scientific training; but having been engaged to finish the woodwork of some electrical machines, he was fascinated by the mysterious power with which he found himself brought into contact, and by the sheer force of native genius and indomitable perseverance, he achieved the great triumph of constructing a machine which marks a new epoch in the history of the industrial arts.*

I will not trouble you any further with details of construction. The machine invented by Siemens of Berlin differs from Gramme's machine only in the way of winding the armature: and the great

*See The Electrician, July 27, 1888, p. 364; and August 24, 1888, pp. 496, 497.

majority of machines now made follow, in the main, one or other of these two types. Though the modifications and improvements introduced, during the last fifteen years, are countless in their variety, yet the same essential elements are common to all machines. There is the armature, or rotating bobbin of wire; there are the massive electro-magnets; there is the commutator, with its numerous copper plates, set edgeways on the axis of the revolving armature; and there are the brushes, which collect the current from the armature, and send it round the coils of the electro-magnet and into the external circuit.

**The Dynamo does not Create Energy.**—Before closing this branch of my subject, I should wish to remind you that the Dynamo does not create the electrical energy it sends forth. It is a law of nature that the sum total of the energy in the material universe, remains always the same: it suffers no loss, and it receives no accession. It is given to man to use it as he pleases; but, in using it, he can only change it from one form to another: he has no power to increase the store, or to annihilate any part of it. We cannot, therefore, get a stream of electrical energy to flow from our Dynamo unless we expend some other kind of energy in producing it; and the energy so expended must be always proportional to the electrical energy we want to produce.




EXPENDITURE OF ENERGY IN PRODUCTION OF ELECTRIC CURRENT.

A Early Form of Siemens' Machine.
*w w* Wires conveying Electric Current.
C Commutator for closing and breaking the Circuit.
P Platinum Spiral.

Let me try to bring this important truth home to you by an experiment. Here is a good-sized specimen of one of the earliest forms of Siemens' machine. It is a machine with permanent magnets, such as I have already described, and is made to be worked by the hand, the armature being driven round by means of this wheel. The binding

## LECTURE II.

### HOW THE ELECTRIC CURRENT IS MADE TO YIELD THE ELECTRIC LIGHT

WHEN an Electric Current passes through a conductor, the conductor is heated; and if the current is strong enough, and the conductor is suitably chosen, it can be raised to a very high temperature, and made to shine with a bright light. This phenomenon may be shown, in its simplest form, by means of a spiral of platinum wire, such as is mounted on this little stand before you.

**Simplest Form of Electric Light.**—I first turn on the current from two cells of a Storage Battery, in the next room: the platinum spiral is sensibly hot to the touch, but there is no glow of light. I add three cells more, and the spiral gets red. I increase the number to eight, and it now emits a pure white light of great brilliancy.

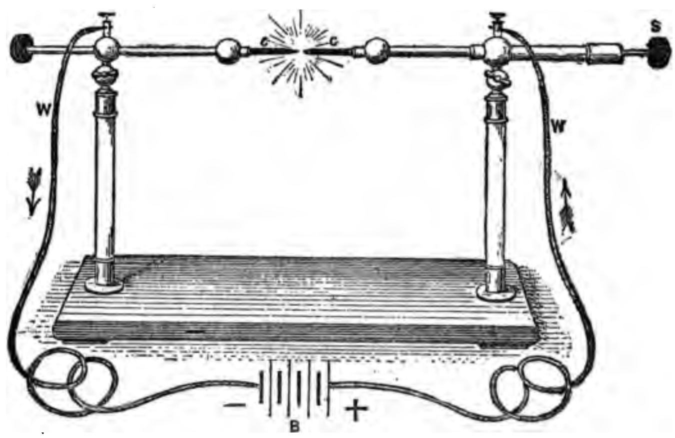
You will expect, perhaps, that I should explain the nature of the process by which heat is thus produced in this wire while the current is passing through it. That is a matter, however, which is not yet perfectly understood. We do not know what the electric current is, in itself; much less do we know what is the nature of the process that goes on in the wire, when, as we say, the current is passing through it; and therefore we cannot really explain how the heat is produced. But we are not altogether ignorant on the subject: we know a little, and that little is easily told. We know that an electric current has energy; we know that it encounters resistance in the platinum spiral, that it overcomes that resistance, and that, in doing so, it expends a part of its energy; and we know that the energy so expended is converted into heat.

Let me illustrate these fundamental conceptions by a familiar example. Every schoolboy knows that if he takes a brass button, and rubs it very hard against a deal board, he can make it so hot that he can hardly bear to touch it. Now, where does this heat come from? You will probably say, "Oh, we know all about that; that's friction." Well, you are quite right: but what is friction? It is a kind of force existing between the surface of the brass button and the surface of the deal board, and tending to prevent the one sliding over the other. But in spite of that force the schoolboy makes the button slide to and fro; in doing so he expends muscular energy: the energy so expended passes away from him forever; and in its stead the energy of heat appears in the brass button and the deal board.

Now we may conceive that the resistance offered by this platinum wire to the electric current is a kind of *electrical friction;* and that the electrical energy expended in overcoming that resistance is converted into heat, just as muscular energy is converted into heat in the familiar experiment of the schoolboy.

An electric lamp, then, is nothing more nor less than a contrivance to convert the energy of an electric current into the energy of heat. It must consist of a conductor which, while it allows the current to flow through it, offers nevertheless a considerable resistance to its passage: and the conductor must be of such material that, when raised to a high temperature, it will glow with light.

**Electric Light first produced, 1810.**—The Electric Light was first produced by Sir Humphry Davy, at the Royal Institution of London, in the year 1810. He employed a battery of 2,000 cells, and he connected the poles of the battery, by means of a stand like this before you, with two carbon rods, which were mounted on the stand. When the two carbon rods were first brought into contact, and then




SIR HUMPHRY DAVY'S EXPERIMENT.

| | | | |
|---|---|---|---|
| B | Battery | C C | Carbon Rods. |
| W W | Wires from Battery to Carbons. | S | Adjusting Screw. |

slowly drawn asunder through a short distance, the current leaped across the intervening space of air, and at the same moment the carbons were intensely heated, and shone with a light of dazzling brilliancy.

I can show you this experiment on a small scale. In the next room there is a battery of twenty-six cells, and the poles of the battery are connected, by these two conducting wires, with the two carbons which you see mounted on the frame before you. At present the carbon points are half an inch asunder, and no current is passing. But by turning a screw provided for the purpose I can bring them into contact: they are now touching, and the red glow that you see at the point of contact shows that the current is flowing. I next reverse the movement of the screw, separating the carbon points by about a quarter of an inch, and a brilliant star of white light fills the space between them.

This experiment of Sir Humphry Davy attracted universal atten-

tion, and awakened a general expectation that so brilliant a light would soon be turned to useful account as an ordinary means of illumination. But the expectation was not destined to be quickly realized. The Voltaic Battery, which was the only means known at that time, and for many years afterwards, of producing an electric current, was too costly and troublesome for general use: and although the Electric Light has long been familiar to scientific men as a useful means of research and illustration, it is only since the development of the Dynamo-Electric machine within the last twenty years that it has emerged from the recesses of the laboratory, and passed into the wider domain of everyday life.

**Two Types of Electric Light.**—You will observe, from the experiments I have already shown you, that there are two different methods of producing light from an electric current: in fact two different types of electric light. In the experiment of Sir Humphry Davy [illegible] a narrow stream of [illegible]. The light produced in this way [illegible] [illegible]

[illegible]

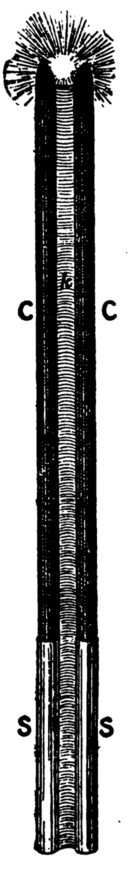
length of time, to keep the carbon rods so adjusted that, notwithstanding the waste that is always going on, they shall remain, nevertheless, at practically the same distance apart. In the apparatus before us such an adjustment may be made by means of this screw, which enables me slowly to advance one of the carbon rods, as the space between them is increased by the process of slow combustion. But when the light is wanted for practical purposes, it is evidently desirable that the adjustment should be made by some kind of mechanism, which shall work of itself without the intervention of any external agency.

**Duboscq's Lamp.**—Such a piece of mechanism was first invented by Foucault of Paris, and was afterwards improved by Duboscq. It is commonly called Duboscq's Electric Lamp. I have it here on the table; and I will try to give you a general idea of the principle on which it works. The carbon rods, as you see, are so fixed in these brass sockets that they are both in the same vertical line, one pointing upwards, the other downwards, with a short distance between them. The lower carbon is permanently connected with the positive pole of a battery or Dynamo, and the upper carbon with the negative pole. Within the case of the lamp there is a clockwork arrangement, which you can see through this glass plate; and when the clockwork is set going, the carbons are made to approach each other. When they come into contact the current passes. At the same moment, an electro-magnet within the case is magnetized by the current, and attracts a small iron bar, which is held suspended by a spring just above the poles of the magnet. The effect of this is twofold. First, the movement of the iron bar pulls asunder the carbon points through a short distance, and starts the light; secondly, it pushes in a small knife edge against a toothed wheel, and stops the clockwork.

As the light continues to shine, the carbon points are slowly consumed by the intense heat. The distance between them is thereby increased, and the current gets feebler. Now the electro-magnet, being fed by the current, gradually loses its strength as the current gets feebler, and relaxes its hold of the iron bar. At last, it can hold it no longer, and the iron bar is pulled up by the spring, the strength of which is carefully adjusted beforehand. When the iron bar is pulled up the clockwork is set free, and the carbon points again begin to approach. As they come nearer to one another, the current gets stronger, and the magnet, regaining its force, pulls down the iron bar again, and stops the clockwork. Since this process may go on indefinitely, the light will be maintained until the current is cut off, or the carbons are burned away.

**New Forms of Automatic Lamp.**—So long as the Electric Light was confined to the laboratory and the lecture hall, this lamp of Duboscq, in one form or another, held almost undisputed possession

of the field. But the recent development of the Dynamo-Electric machine gave a new impulse to invention; and there are now before the world a countless variety of lamps suitable for the production of the Arc Light. You may see them, of various shapes and forms, at the railway stations and in the public squares of nearly all the capitals of Europe, and they are distributed even more abundantly over the great continent of America. Some of them, no doubt, leave much to be desired in point of steadiness and certainty of action; but many of them, on the other hand, work with a degree of smoothness and precision which almost justifies the enthusiastic descriptions by which they are heralded into public notice. I will not trouble you with the details of their construction. Enough it is to say that they all aim at the same end, namely, to keep the carbon points at a constant distance from each other, notwithstanding the fact that they are always wearing away by combustion.



THE JABLOCHKOFF CANDLE.
C C Carbon Rods.
k k Insulating Layer of Paste.
S S Brass Sockets to be connected with Battery or Dynamo.

But no matter how perfect the mechanism of these lamps may be, the Arc Light is always, from its very nature, an unsteady light. The distance between the carbon points first increases as the carbons are consumed, then it is diminished when the mechanism comes into play, then it increases again; and so on, indefinitely. Now every change in the distance between the carbons produces a change in the resistance of the arc; and every change in the resistance of the arc produces a change in the intensity of the light. Thus the light is, of necessity, constantly varying in intensity; and the highest aim of inventors has been to reduce such variation within the narrowest possible limits. Absolute steadiness of the light seems hardly attainable: the most that can be hoped for is a near approximation to steadiness.

**The Jablochkoff Candle.**—About twelve years ago, a great sensation was produced by the introduction of a new form of Arc Light, under the name of the Jablochkoff Candle. Monsieur Jablochkoff was an officer in the Russian army; but as soon as he conceived the idea of his Electric Candle he resigned his commission, and came to Paris. Here he took out a patent for his Candle, opened a workshop for the manufacture of it, and in a few months made himself famous as the inventor of a new form of Electric Light.

I have here a few specimens of the Candle. It consists, as you see, of two carbon rods, about ten inches long, placed parallel to one another, and kept at a distance of about a quarter of an inch all along

their length, by a solid layer of white pasty matter which acts as a non-conductor. The composition of this paste is an important feature in the manufacture of the Candle: various substances have been tried at different times; but I believe the most effective is now found to be a mixture of baryta and plaster of Paris. The carbon points project about a quarter of an inch beyond this insulating layer; and a small bridge of some conducting material is laid across, to enable the current to pass from one to the other.

When the Candle is mounted for use, one carbon is put in connection with the positive pole of the dynamo or battery, by means of the brass socket in which it is fitted; and the other carbon is similarly put in connection with the negative pole. The current, not being able to force its way across the insulating layer that separates the two carbons passes up through one, then across the bridge, and down the other. The bridge is at once consumed by the heat generated and the Arc Light is started between the two points. In the intense heat of the Arc, the insulating layer is melted and consumed; and the whole Candle burns slowly away in the course of about two hours. The intensity of the light is equal to from two to three hundred candles.*

There is an interesting little bit of scientific history connected with this invention. Jablochkoff had read in text-books on Electricity that the positive carbon is consumed twice as fast as the negative; and he said, "I will provide for that by making my positive carbon twice as thick as my negative, and so they will burn down evenly together." He accordingly made his Candles, in the first instance, with one thick and one thin pencil of carbon; the thick pencil being always connected with the positive conductor, and having twice as great a sectional area as the thin one.

But this ingenious device did not stand the test of practical experience. On the one hand, the positive carbon did not burn away exactly at the rate which had been calculated upon; while, on the other hand, the negative carbon, offering a greater resistance to the current, became red hot along a considerable portion of its length, and was thus sensibly reduced in thickness, by slow combustion at its surface. Owing to these causes the Candle was found to burn very irregularly, and generally went out at the end of about a quarter of an hour.†

The first Candles then were a failure. But the inventor soon found another resource. You may remember I explained, in my last Lecture, that a dynamo can give us currents alternately in opposite directions, or currents continuously in the same direction, according to the mode of its construction. Jablochkoff, then, conceived the idea of using a machine which would give currents alternately in opposite

*For a full account of the Jablochkoff Candle, see the elaborate work just published by Hippolyte Fontaine, Eclairage à l'Electricité, Paris, 1888, pp. 376–381.

† Id. *ib.*, p. 377.

directions. Thus each carbon would be alternately positive and negative: they would therefore be equally consumed, and if made of exactly the same thickness they would burn down evenly together.

This new Candle at first promised to be a great success. It was taken up in Paris, and used instead of gas along the whole length of the Avenue de l'Opéra, as well as on the Place du Théâtre Français, at one end, and the Place de l'Opéra, at the other. In London, too, it was adopted on the Thames Embankment, from Charing Cross Station to the House of Parliament. But it failed to fulfil the high hopes which it had awakened. Perhaps the clearest evidence of its failure is that they have taken down all the Electric Candles on the Avenue de l'Opéra, and I am sorry to say have gone back again to gas.

The cause of the failure is due, I think, in great measure, to the insulating layer of paste. When the current passes across from carbon to carbon, this paste is melted and vaporized, and produces a sort of flame with a varying tinge of color. Moreover, there seems to be a constant change of resistance, according to the condition of the paste, at any given moment; and this gives rise to a great unsteadiness in the light. At all events, whatever the cause may have been, the Jablochkoff Candle, though at first received with great enthusiasm, has been generally found unsatisfactory; it has been almost completely abandoned in England, and it is not likely to be heard of much more in the history of Electric Lighting.

I should say, however, that the Electric Candle still seems to find favor in France. According to the most recent accounts it is still manufactured, in that country, at the rate of a million and a-half a-year. At Havre, it is used to illuminate the port; and in Paris, it is familiar to all visitors, at the Magasins du Louvre and the Magasins du Printemps. It appears that, between these two establishments, somewhere about 465 Jablochkoff Candles are in daily use. But in the more famous mart known as the Bon Marché, which has recently been fitted up with one of the finest Electric Light installations in the world, there are only 96 Electric Candles, while there are 290 Arc Lights of the ordinary kind, and 1808 Incandescent Lamps of the Edison type.*

**The Incandescent Light.**—I now come to speak of the Incandescent Lamp. In this form of lamp, the conductor through which the current flows is continuous: that is to say, there is no point in the circuit where the current has to leap across a stratum of air, as in the Arc Lamp. But the resistance of the circuit is so adjusted as to be concentrated on some one part of the conductor, which is thus made to glow with intense heat, when the current passes. The simplest example of such a lamp is the platinum spiral which I have already shown you, and which, I may say, has been before the world

* See Eclairage à l'Electricité, par Hippolyte Fontaine, Paris 1888, pp. 380, 544–551.

for nearly fifty years. The current, coming from a battery of ten cells in the next room, is here conveyed for the most part through a stout copper wire, which offers little resistance, and is therefore only slightly heated: but, at a certain point in the circuit, a spiral of platinum wire is interposed in the path of the current, for a space of two or three inches. The platinum wire offers considerable resistance; intense heat is therefore produced in this part of the circuit; and the wire glows with a rich white light.

This platinum spiral is, in some respects, a very perfect little lamp. Platinum has no tendency to combine with oxygen, even when raised to a high temperature, and no matter how often it is made incandescent, it is not consumed. It glows with light when the current passes; and it returns to its former state when the current is shut off. One would almost think that a lamp of this kind should last for ever. But it has one fatal defect. Every metal has its own melting-point, that is to say, a certain definite temperature at which it will melt. The melting-point of platinum is estimated at about 2,000 degrees centigrade; and to yield a really good light it must be raised to the very verge of melting. Hence, in order to get an effective light from incandescent platinum, we must keep it so close to its melting-point that a slight irregularity of the current may, at any moment, cause it to melt, thus breaking the continuity of the circuit, and extinguishing the light.

I should like to bring this point home to you by an experiment, though the experiment involves the sacrifice of my lamp. At present the current flowing through this spiral is carefully regulated, to make it glow with a fairly good white light. But I can increase the strength of the current, either by adding more cells to the battery, or by cutting out some resistance from another part of the circuit. The latter method is the more delicate, and the more convenient for our purpose. You see on the wall a rectangular frame containing twelve stout carbon rods. This is called a resistance-board. At present these carbon rods are part of the circuit, so that the current must flow through them all, one after another. But by turning a handle, I can cut out two or more at pleasure, and so reduce the resistance by small degrees.

I now turn the handle, and cut out two carbon rods. The resistance is slightly reduced, the current becomes stronger in proportion, and you see the platinum spiral shines with increased brightness. I advance the handle another stage, and cut out two more carbons. The platinum spiral is more brilliant still; but its brilliancy lasts only for a moment; its melting-point has been reached; the circuit is broken; and the light disappears.

You will say, perhaps, that we might avoid this danger if we contented ourselves with a less brilliant light. Quite true: but that

is just what we will not do. Having once seen what a brilliant light the electric current can give us, we will not be content with a platinum spiral that gives us only the light of two or three candles. Hence, after many ingenious attempts of Mr. Edison to produce an effective lamp, first with platinum alone, afterwards with an alloy of platinum and irridium, this form of lamp has been reluctantly abandoned, at least for the ordinary purposes of illumination.

**Carbon versus Platinum.**—Now the property that platinum wants is possessed in a very high degree by carbon. I have already said that carbon cannot be melted by any kind of artificial heat yet known. Hence it was recognized long ago that, if we could substitute for this platinum spiral a slender rod of carbon, we might raise it to the most brilliant incandescence without any fear of melting it. But unfortunately carbon has another property which would be fatal to such a lamp. It would not melt, but it would be consumed. Carbon, when raised to a high temperature, has a great affinity for oxygen; and if our carbon lamp were exposed to the air, as we have exposed our platinum lamp, the carbon, when raised to incandescence, would combine with the oxygen of the air, to form carbonic acid, and would be burned away in a very short time.

The remedy for this defect is easy to see, and was tried so long ago as the year 1845, by an American inventor named King. He got a thin pencil of carbon, mounted it on a frame within a glass vessel, and then exhausted the air from the vessel, by a process similar to that by which a Torricellian vacuum is produced in a barometer tube. This lamp, however, was a failure. The carbon pencil received the electric current by means of a metal rod passing through the glass vessel; and sufficient air soon found its way through the joint thus established to cause the combustion of the carbon.

I may say that practically no progress was made with this form of Electric Light, from the time of King until the year 1879, when Mr. Edison of New York, and Mr. Swan of Newcastle, startled the world by the production of those beautiful incandescent lamps which are inseparably associated with their names. Other inventors quickly appeared in the field; numerous patents were taken out; and various claims to priority were advanced. I need not dwell upon these claims, or on the controversies to which they have given rise. It is enough to say that the incandescent lamp, which had awakened such hopes, and such fears too, when first announced to the world, was rapidly brought to a high degree of perfection; and by the time of the Paris Electrical Exhibition, in 1881, it was already fully established as a magnificent success.

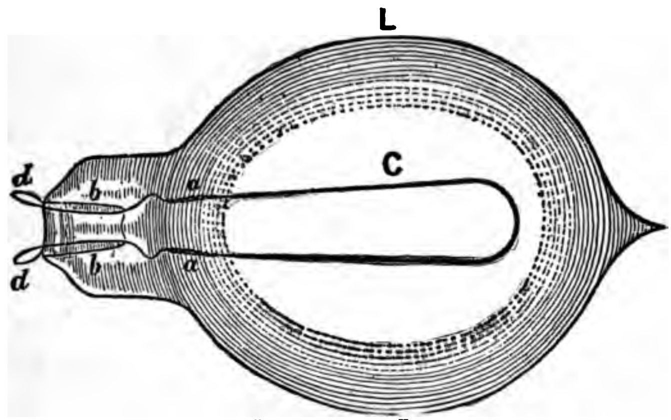
**A Perfect Vacuum.**—The name of Mr. Crookes of London is not often mentioned in connection with electric lighting; and yet Mr. Crookes has contributed, in no small measure, to the production of the incandescent lamp in its present form. The lamp consists of a thin

filament of carbon mounted in a glass globe from which the air has been exhausted. In its essential principle, therefore, the lamp does not differ from the lamp invented by King forty years ago. But King's lamp failed for want of a good vacuum; and Mr. Crookes is the man to whom we are mainly indebted for the almost perfect vacuum of the modern lamp. The history of this matter is interesting and curious.

Mr. Crookes was engaged, between the years 1873 and 1878, in making experiments with his well-known radiometer. For these experiments he required a vacuum far more perfect than any which had been previously known. He therefore applied his rare powers of invention and contrivance to the improvement of Sprengel's mercurial air-pump. And so great was his success that we are now in possession of an air-pump which, with ease and certainty, can reduce the density of the air within a glass globe considerably below the millionth of an atmosphere.

With such a vacuum placed at their disposal, the difficulties in the way of inventors, occupied with the development of the Electric Light, were already half conquered: and accordingly it is not wonderful that, between the year 1878 and the year 1881, a number of different lamps, with more or less claims to originality of invention, should have been brought into public notice. The most successful of these lamps were those of Mr. Edison and Mr, Maxim in America, and of Mr. Swan and Mr. Lane-Fox in England.

**Incandescent Lamp with Carbon Filament.**—The essential elements of an incandescent lamp, as now made, are a thin filament of



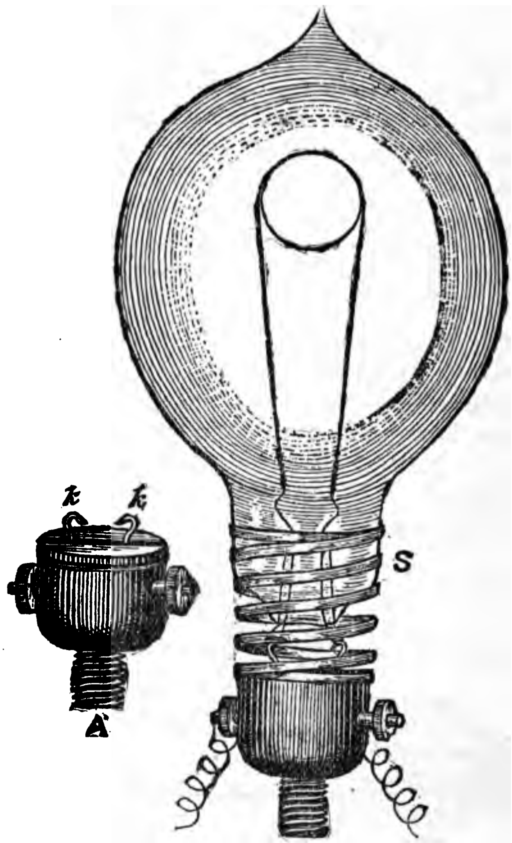

THE INCANDESCENT LAMP.

L Glass Globe exhausted of Air.
C Thin Filament of Carbon.
*b b* Platinum Wires attached to Carbon Filament at *a a*, and looped outside the Glass at *d d*.

carbon, a glass globe, and a perfect vacuum. Here is one of the most recent construction; but you will see the details more distinctly on the diagram before you. L is the glass globe from which the air has been almost completely exhausted: C is the carbon filament; *b b* represent the platinum wires, which pass through the glass, and are formed into

loops outside at *d d;* and *a a* show the points of attachment connecting the carbon filament with the platinum wires.

In order to connect the platinum wires with the opposite poles of a Dynamo or Battery, it is usual to provide for each lamp what is called a Holder. The Holder of the Swan lamp, which you see here on the table, and which is also represented in the diagram on the wall, is

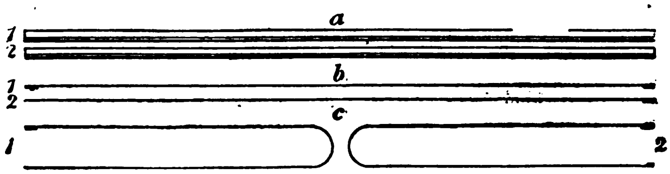



INCANDESCENT LAMP AND HOLDER.

A Holdre showing Hooks at *kk*. | B Lamp ou Holder showing Spring at S.

extremely simple. It consists of a button of ebonite or hard wood, with two binding screws, to which the wires from the Battery are attached, and which are themselves connected with two hooks, *k k*. You see how easily the lamp may be fitted on to these hooks, by means of the platinum loops which are left exposed outside the glass globe. But to secure more perfect contact, a spiral spring is interposed between the Holder and the lamp, which tends to push them away from one another, and thus maintains a steady pressure at the points of contact. I now take a lamp and fit it on to the Holder, and you see it ready for use.

**Preparation of the Carbon Filament.**—Next to the vacuum, which is now always produced by one form or other of the mercurial air-pump, the most important feature in the lamp is the carbon filament. This filament is variously made. The most essential property, recognized by all, is that it should be of uniform thickness and uniform structure throughout its whole length, so that it shall offer, at every point, exactly the same resistance to the passage of the current. Mr. Edison after numerous experiments with a great variety of vegeta




PREPARATION OF FILAMENTS FROM BAMBOO CANE.

*a* Flat Strips of uniform Character.
*b* The same narrowed down to thickness of a thread.
*c* The same bent into Shape and ready for Carbonization.

ble fibres, selected the bamboo cane as the most suitable for his purpose.

Having first removed the hard silicious outer coating, he prepares a number of strips perfectly flat and straight, of the required length as shown in the diagram at *a*. Each of these he shaves down to a uniform thickness along its whole length, with instruments which he has specially devised for the purpose. He then narrows them to the fineness of a thread, leaving a small projecting piece at each end. They are thus reduced to the condition shown at *b* in the diagram. Lastly, these fine threads of bamboo fibre are bent into shape as shown at *c*, and fitted into moulds to be carbonized.

Mr. Swan, in the first instance, used cardboard as the material from which he manufactured his carbon filament; afterwards he tried bibulous paper, which he treated with dilute sulphuric acid; but he finally settled down to ordinary cotton thread as giving the most satisfactory results. He steeps the cotton thread in dilute sulphuric acid, giving it thereby somewhat of the character of parchment, then twists it into the shape required, and prepares it for carbonization. This is the process, I believe, now commonly followed by the Edison-Swan Company. The carbon filament produced by it is said to be very tough, and as hard and stiff as a metallic wire.*

In the process adopted by the Anglo-American Brush Company, cotton wool is the material employed. It is first dissolved in chloride of zinc, and being slightly heated is reduced to a viscous or semi-fluid condition. It is then forced through a small orifice under the pressure of a head of mercury, and, coming out in a thread-like form, is received in a vessel of alcohol, where it solidifies. Lastly, it is placed

in another vessel of alcohol, which dissolves all impurities; it is then dried and carbonized.*

The process of carbonization is practically the same for every kind of filament. The vegetable fibre, having been prepared in any of the various ways above described, is packed in powdered charcoal in a closed vessel, and then gradually raised to a white heat, at which it is kept for several hours.

When the carbon filament is ready for use, the ends of it are carefully attached to the ends of two platinum wires, and it is introduced into a glass globe, the neck of the globe being raised to a melting temperature and closed in round the platinum wires, so as to form a perfectly air-tight joint. It only remains then to exhaust the air from the globe, which is done by means of a glass tube, which serves to connect it with a mercurial air-pump.

During the process of exhaustion a current of electricity is sent through the carbon filament, which is thereby raised to incandescence, and freed from the air and other gases that might otherwise have remained shut up within its pores. When the exhaustion is complete, the tube connecting the globe with the air-pump is removed, and the orifice in the globe is closed in the blow-pipe flame.

**Light without Heat?**—There are some questions of practical interest connected with the Electric Light on which I should wish to say a few words, before bringing this Lecture to a close. First, I may notice a general impression which seems to prevail that, in the case of electric illumination, we have light without heat. Now I have shown you that, in both forms of the Electric Light, the carbon becomes luminous simply because it is made intensely hot. You have seen, in fact, that when a platinum wire is used instead of a carbon filament, in the incandescent lamp, there is danger of melting the wire, though its melting-point is somewhere about 2,000° C., which is higher than that of any other metal.

Again, in the arc lamp, the heat of the carbon points is absolutely the greatest artificial heat known. To give you some idea of this intense heat, I turn on the current to this arc lamp on the table, and now when I hold a stout platinum wire close to the positive carbon, it melts like sealing wax in a candle flame. A steel rod, held in the same position, sends out a brilliant shower of sparks in all directions. It is therefore an error to say that in either kind of electric lamp we have light without heat.

Nevertheless, there is an important germ of truth in the common

*It is interesting to note that this process has been the subject of a protracted law-suit, in which the Edison-Swan Company were the plaintiffs, and the Brush Company were practically the defendants. It was contended on the part of the Edison-Swan Company, that they had the exclusive right to manufacture lamps with carbon filaments. But the learned judge refused to admit this claim, and gave judgment in favor of the Brush Company. The history of the incandescent lamp was very fully brought out during the progress of the trial, and is set forth with great clearness in the luminous judgment of Mr. Justice Kay. See The Electrician, May, June, July, 1888.

belief. If you look closely at the filament of an incandescent lamp, you will see that, although three or four inches in length, it is exceedingly thin. It has, therefore, a very small volume: the volume of an ordinary gas flame is probably several hundred times as large. Hence though the intensity of the heat in the filament, that is, its temperature, is very great, the quantity of heat is comparatively small. It has been estimated that, for the same amount of illumination, a gas flame gives out more than fifteen times as much heat as an incandescent electric lamp, and wax candles more than twenty-five times as much. Similarly in the case of the arc light, the incandescence of the carbon points is confined to a very small volume, and the quantity of heat generated is proportionally small.

**The Arc Light and the Incandescent Light compared.**— Next, perhaps, you would like to hear some opinion as to the relative merits of the arc lamp and the incandescent lamp. I would say that each is excellent in its way; but they are suited for quite different purposes. First, let me say something of their relative cost. For a given expenditure you can get eight or ten times as much light from the arc lamp as you can from the incandescent lamp. Every horse-power in your engine will maintain about eight incandescent lamps, giving a light of sixteen candles each, or say a hundred and thirty candles in all: whereas the same power with an arc lamp will give an average light of a thousand to twelve hundred candles.

The arc light, however, is quite unsuited to the interior illumination of houses. It is too dazzling and it is too unsteady; perhaps I should add that, owing to the predominance of blue and violet rays in the arc light, it gives a weird and haggard appearance both to people and to things. On the other hand, it is admirably fitted for all kinds of illumination out of doors; for the illumination of streets and railway stations, of public gardens, docks, and harbors, in a word, of all places where people congregate or work is to be done.

The incandescent lamp comes in most efficiently just where the arc lamp fails. It gives a rich soft light in which brilliancy and steadiness are combined, and is admirably suited for interior illumination. It is pre-eminently the light for public institutions of every kind; museums, libraries, and picture galleries, hotels and theatres, shops and factories; and I may say it is the ideal light in private houses and on ship-board. Let us compare it, for a moment, with the other modes of illumination at present in use.

**Comparison with other kinds of Light.**—Every other artificial source of light, whether gas, or candles, or oil, takes out of the air the oxygen which is necessary for the support of life, and gives back, in return, carbonic acid, which tends to produce suffocation: whereas the incandescent lamp takes nothing from the air, and it gives nothing to it but pure and simple light. Again, the incandescent lamp pro-

duces far less heat, as we have seen, for a given amount of illumination, than other sources of light. Once more, oil and candles and gas often produce a disagreeable smell, and always produce more or less smoke, which discolors the walls and ceilings of your rooms, injures your paintings and the bindings of your books, and disfigures every kind of decorative work. The incandescent lamp produces no smoke, and what to many is, perhaps, even more important, it produces no smell.

A very remarkable testimony to the healthfulness of the incandescent lamp, as compared with gas, was given by Mr. Preece, at the Meeting of the British Association recently held in Bath. About two years ago, the Electric Light was introduced into the Central Post Office Saving Bank, in London; and since that time, the leaves of absence, on account of illness, of members of the staff, have been reduced by an amount equal to an average of two days a year for each person. This, he said, was equivalent to a gain to the service of the time of eight clerks, and represented a saving of about £640 a-year in salaries.*

As regards the danger of fire, it is not easy to exaggerate the extraordinary safety of the incandescent lamp. I would only call your attention to one fact. In dealing with gas and candles, we are dealing with a naked flame, whose function it is to set fire to whatever touches it; in the case of the incandescent lamp, we are dealing with a light shut up in a prison house of glass, and if we chance to break the glass, we at the same moment put out the light.

**Is the Electric Light now available for use?**—But the most important practical question still remains behind: Is the Electric Light at present really available for use, so that we may have it, if we choose, without reasonable fear of disappointment? This is a question I must answer in parts; and I would ask you to remember that I express only my own opinion, founded on such information as I have had access to. First, as regards the arc light, it is perfectly available for all purposes of out-of-doors illumination; and you can have it when you please, with certainty, with efficiency, and with economy.

Secondly, with respect to the incandescent light, I would say it is available for every public institution and for every private house that is large enough, or rich enough, to afford the expense of a separate installation. Where a large number of lights, say one or two hundred, are required for several hours every day, I believe that a separate installation may be set up and maintained with economy, as compared with other modes of illumination. Hence I hope to see the Electric Light established here in our new Museum and in the National Library, as well as in the National Gallery and the Museum of Natural History. This splendid group of buildings, designed to be a great centre of education and culture for the people, offers a field for the

*See Address to the Mechanical Section of the British Association 1888, by W. H. Preece, F.R.S., President of the Section.

introduction of the Electric Light which, so far as I know, stands almost unrivalled.

In like manner, an Electric Light installation may be established with economy in factories and workshops, in theatres, clubhouses, and large hotels. In private houses, on the other hand, where the number of lights required would be less that a hundred, a separate Electric Light installation would probably be found more costly that other means of illumination. But it would be a luxury: and I can say, with confidence, that this luxury is now available for every one who may wish to have it, and can afford to pay for it.

**Lighting from a Central Station.**—So much for separate installations. A question of still wider interest has probably suggested itself to most of you: Is it possible to supply the Electric Light to all the houses of a given area, from a central station, as gas is now supplied? This is a problem which is just now the subject of experiment on a large scale: and when a practical question has been submitted to the test of experiment, it is wiser, I think, not to prophesy until we know the result. I may tell you, however, what has been already done. About two years ago, a central station was established close to the Grosvenor Gallery, in London; and, at the present moment, this station supplies electric currents for about 30,000 incandescent lights, scattered over an area of somewhat more than a mile radius. This is the largest experiment of the kind, so far as I know, that has yet been carried out in England; but how far it may be regarded as a practical success it is impossible to judge until we know, upon sufficient authority, the exact facts connected with the working of the system.

**Transformations of Energy.**—And now, in conclusion, let me remind you, even at the risk of repetition, that in setting before you this slight sketch of the history and development of the Electric Light, I have given you, at the same time, as I believe, a striking illustration of those wonderful transformations of energy that are forever going on around us, both in the operations of Nature and in the works of man. In my last Lecture, I sought to bring home to you that the Dynamo is nothing more then a machine for converting the energy of mechanical motion into the energy of an electric current: and in my Lecture to-day I have shown you that the various forms of electric lamp are only so many contrivances for converting the energy of the electric current into the energy of heat and light.

If I were to trace back the history of these transformations farther towards their source, we should find that the mechanical energy which drives the Dynamo is derived from the stored-up energy of coal; and the coal comes from the vegetation of a long past time; and that ancient vegetation was quickened into life by the energy of the sun's rays. Thus it would seem that this beautiful light, which

the Science of our time has called forth to illuminate our streets and our houses, does but bring back to us the energy of the primeval sun, which for long ages appeared to be lost, but was in fact carefully stored up for our use; and the saying of the Roman poet, "Omnia mutantur nihil interit," receives a deeper and a fuller meaning than even he himself would probably have attached to it.

# THE STORING
OF
# ELECTRICAL ENERGY.

A LECTURE

DELIVERED IN THE THEATRE OF THE ROYAL DUBLIN SOCIETY,

*MARCH, 1882.*

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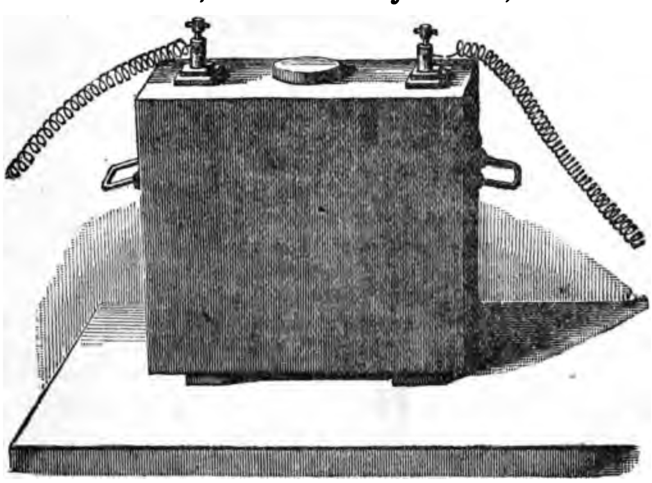
## THE STORING OF ELECTRICAL ENERGY.

IN the early part of last summer, an account was published in The Times newspaper of a "marvellous box of electricity," one cubic foot in size, which, it was said, had been carried from Paris to Glasgow, and there deposited in the laboratory of Sir William Thomson. A few weeks later, a letter appeared from Sir William Thomson himself, stating that he had carefully examined the box; that he had found it to contain a million foot-pounds of energy; and then when this store was exhausted, it could be easily renewed, so as to be again



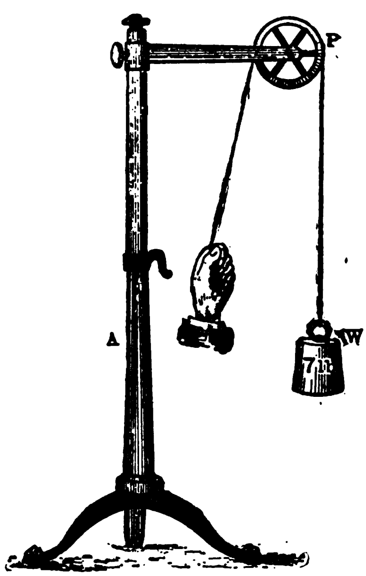
THE "MARVELLOUS BOX OF ELECTRICITY."

ready for use. Further, he told us, in effect, that a few of these boxes, laid by in a cellar, might be charged from time to time from a central factory, and might be used as occasion required, either to drive

machinery, or to light up a drawingroom. With the aid of such boxes, a tramcar might dispense with horses, and a railway train with steam engines. Nay, he said, the vast energies of the Falls of Niagara might be stored up in these wonderful boxes, and used as the chief source of light and power for the whole continent of North America.

These statements are, perhaps, tinged with the glow of enthusiasm, naturally excited in a great mind, when it contemplates the first dawn of a new discovery, and glances forward, by anticipation, to its future history. But the simple facts of the discovery, even when expressed in the sober words of science, are quite sufficient to account for the wide-spread interest it has awakened. This "box of electricity," as it has been called, is nothing more or less than a kind of store, in which electrical energy is laid by, so to say, and kept ready for use when wanted. Its practical value can be fully determined only by actual trial: but this much may be said, even now, that it gives fair promise of bringing more completely under our control one of the most potent and mysterious forces of nature.

My object to-day is to give you some account of this new discovery; to tell you what it is in itself, and how it stands in relation to our previous knowledge; how it comes opportunely, as it were, to fill a vacant place, and puts it in our power to deal with the energy of the electric current as we have long been accustomed to deal with other forms of energy.



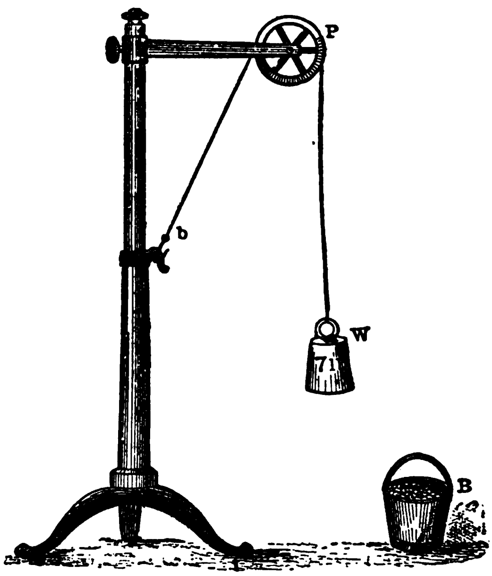

ENERGY EXPENDED IN DOING WORK.

A Stand supporting the Pulley P. | W Weight of 7lbs., lifted up one foot.

**Example of Energy Stored up.**—At the outset, let me try to bring home clearly to your minds what is meant when we speak of

storing energy. Energy is the capacity of doing work; and it is measured by the amount of work that is done when the energy is expended. Here is a weight of seven pounds resting on the table. It is tied to one end of a string which passes over a pulley. When I pull down the other end of the string, I pull up the weight, say to a height of one foot. In doing so, I expend a certain amount of energy, and I do a certain amount of work. If I call the work done, when a pound weight is lifted one foot high, a foot-pound, then the work done, when a weight of seven pounds is lifted one foot high, will be seven foot-pounds; and this is the measure of the energy I have expended in pulling up the weight before you.

Now I want to show you that the energy so expended is stored up in the weight, so long as it remains in the position to which I have raised it. You know that if I leave the weight to itself, it will fall back to the table, and that in falling back it is able to do work: therefore, in virtue of its present position, it has the capacity of doing work; that is, it has energy. I may store up that energy indefinitely, by




Energy Stored up in a Suspended Weight.

A Stand supporting the Pulley P.
B Bucket filled with Shot.
W Weight kept suspended by the Hook *b*.

simply hooking on the string to this stand, so as to keep the weight suspended at a height of one foot from the table. But, on the other hand, I may draw upon my store of energy whenever I please, and use it to do work. Here is a little bucket of shot, which weighs somewhat less than seven pounds. I hook it on to the free end of the string, and then let go. The weight falls down one foot, and the bucket of shot goes up one foot.

If we consider the work done, by the falling weight, on the bucket of shot, we shall see that it is a little less than seven foot-pounds, since the bucket of shot weighs somewhat less than seven pounds. But the falling weight has done another kind of work: it has overcome the friction of the pulley. And moreover, when it reached the table it had still a little energy left, which is expended in a feeble blow. Now, if we were to measure the energy of that blow, and add it to the energy spent in overcoming friction, and add both, taken together, to the work done on the bucket of shot, the whole would be equal to seven foot-pounds of work; and thus we should find that our weight, in falling back to the table, did work which is the exact equivalent of the energy I had expended in pulling it up. In this sense, the energy expended by me may be said to have been stored in the uplifted weight.

You will find an interesting illustration of this principle in a common eight-day clock. The works of the clock are driven by the weights; and the weights, in doing their work, are always falling slowly towards the ground. When at length they can fall no further, they can do no more work, and the clock is said to have run down. If we want to set it going again we must wind it up; that is, we must lift up the weights into a position from which they can fall down again. In doing so, we expend muscular energy, and the energy so expended is practically stored up in the weights, to be given out slowly and continuously, in the form of work, as they fall back towards the ground, during a period of several days.

In like manner, when you wind up a watch, you lay in a store of energy, by coiling up an elastic spring; and the spring expends this energy in doing work, as it slowly uncoils itself, and imparts motion to the wheels of the watch. Again, when I pump air into this air-gun, I lay up a store of energy in the form of compressed air; and I can draw upon that store at pleasure, and use it for the purpose of discharging bullets from the barrel of the gun.

It would be easy to multiply examples; but my object is not so much to treat this branch of the subject exhaustively, as to suggest familiar illustrations of a general principle. Everyone can supply new examples from his own experience. Thus a steam-hammer lifted up has a store of energy, which it expends, in doing work, when it falls, by its own weight, on the anvil. A cross-bow stretched has a store of energy, which is ready at any moment to send an arrow flying through the air. A cannon-ball discharged from the mouth of a cannon has energy stored up, which does work in tearing asunder the massive armor of an iron-clad vessel. The fly-wheel of a gas-engine receives, at each explosion, a store of energy, which it expends in keeping up movement of the machinery until the next explosion comes.

**Energy Stored up in Clouds and Rivers.**—Sometimes energy

is stored up for us by a natural process, and we have nothing to do but to use it. You have seen that there is a store of energy in an uplifted weight, and that we may use this energy for the purpose of doing work, as the weight falls back to its former level. But it may not have occurred to you that Nature is always busy, laying up for us a store of energy of this kind, which is practically inexhaustible. She is always lifting up the water of the ocean in the form of vapor, and setting it down again on the summits of our hills and mountains, in the form of rain and hail and snow. There it gathers into rivulets, and the rivulets coming together form streams, and the streams sweep down into the valleys, and flow back as stately rivers to the parent ocean. And all along its course, this falling water, as you know, has within it a store of energy, which it is ever ready to give out in doing work for us—in grinding corn, or in sawing timber, or in driving machinery.

**Energy Stored up in Coal-Mines.**—So much for the storing of what may be called mechanical energy. I should now wish to give you one or two illustrations of the way in which the energy of heat may be stored up. I need not tell you how largely the energy of heat is employed, in the form of steam, to do the work of the world. Now we get this heat, as a general rule, by the combustion of coal; and therefore a coal-mine is a vast store of energy, always available to drive our machinery and to do our work.

Here, again, we are indebted to the beneficent foresight of Nature. Long ages ago this store of energy was laid up for us, in the primeval forests of that ancient time which is known to geologists as the Carboniferous Period. The rich and luxuriant vegetation of those primeval forests was mainly composed of certain chemical compounds of carbon and hydrogen, which were drawn off from the air and the earth by the action of natural forces, and built up into the structure of plants and trees. Ages rolled by; generation after generation of that ancient life flourished and decayed; the dry land was submerged beneath the ocean; new strata were spread out over the sunken forests; and by a slow and gradual process the vegetation of that long-past time was compacted into beds of coal. But after all these changes, the hydro-carbon compounds, built up in the primeval forests, still survive in the coal, and constitute, in fact, the source of all the heat that is given out when coal is burned.

It is worth while to pause for a moment, and consider the actual process of combustion by which this heat is developed. Hydrogen has a great natural attraction for oxgyen, and so has carbon. In consequence of this attraction they are ready, under certain conditions, to part company with one another, and to combine, each of them, with oxygen, thus forming new chemical compounds. When we light a fire we produce the required conditions, and the process then goes on until

all the coal is burned away. The hydrogen combines with oxygen, and forms water; the carbon combines with oxygen, and forms carbonic acid. Thus the coal is converted, by combustion, into water and carbonic acid; a small quantity only, which is incombustible, remaining behind in the form of ashes.

But what is the physical cause of the heat produced in this process? You remember that a weight in falling to the ground, under the attraction of gravitation, can do work for us. If, however, it be allowed to fall without doing work, it reaches the ground with its full store of energy unimpaired, and expends it all in a single blow. Now it has been fully demonstrated by experiment that, by this blow, the energy of the falling weight is converted into the energy of heat. And it would seem that the heat produced in combustion is generated by a somewhat similar action. The atoms of hydrogen and carbon clash with the atoms of oxygen, and heat is evolved in the collision. In the case of a fallen weight, a mass of sensible magnitude, moving through a sensible distance, strikes against another mass; in the case of combustion, millions upon millions of minute atoms, moving through indefinitely small distances, strike against each other. But in both cases alike, the energy of moving bodies is converted into the energy of heat.

**Energy Stored up in Separated Gases.**—And now we can see more clearly what it is exactly that makes coal a store of heat energy; it is the fact, that in coal we have carbon and hydrogen, on the one hand, existing apart from oxygen, on the other, with a chemical force acting between them, and tending to pull them together. Proceeding from this idea, it is easy to conceive how we can lay up for ourselves a store of this kind of energy. Water, as you know, is a chemical compound of oxygen and hydrogen. Now, on the table before you is a voltaic battery, and near the battery is a glass vessel containing acidulated water. When I send a current of electricity from the battery through the water, the molecules of water are pulled asunder by the action of the current, and resolved into their constituent elements. You can plainly see the gases as they rise in multitudes of bubbles, in these two glass tubes, which are now brilliantly illuminated by a beam of light from the lantern. The oxygen is set free in the tube to your left, where the current enters the liquid; the hydrogen in the tube to your right, where the current leaves the liquid.

What I want you to observe, in this beautiful and interesting experiment, is, that we are here expending a certain kind of energy—the energy of an electric current—in doing a certain kind of work, that is, in pulling asunder the atoms of oxygen and hydrogen against the force of attraction, which tends to keep them locked together in close chemical union. The two gases, thus forcibly separated, have a strong tendency to combine again, and when they do combine, they will generate new energy in the form of heat.

To impress this important fact distinctly on your minds, I will now get these gases to combine chemically before you. You see on the table, side by side, two small bags, one filled with oxygen, the other with hydrogen. And here is an apparatus known as the oxy-hydrogen lamp. It has one tube connected with the bag of oxygen, another with the bag of hydrogen. The two tubes communicate, by means of these stop-cocks, with the same common jet, where I mean to bring the gases into intimate contact, under circumstances favorable to their chemical combination.

First turning one of the stop-cocks, I allow the hydrogen to flow out, and when a lighted taper is applied to the jet, the hydrogen burns with a pale blue flame. This flame, though but faintly luminous, is intensely hot, as I can easily show you. Here is a spiral of platinum wire, and you see, when it is held in the flame, it at once begins to glow with a steady white light. The heat that is here produced is due to the combination of the hydrogen, coming from our bag, with the oxygen present in the air around us. But it becomes far more intense when I turn the second cock, and thus pour a stream of pure oxygen into the jet of glowing hydrogen. To give you some practical evidence of the heat that is now yielded up by our store of energy, I take this piece of steel wire and hold it in the flame. See how it burns away like tinder, and scatters about a shower of brilliant sparks. I put aside the wire, and in its stead I hold a rod of chalk in the burning jet. The chalk does not burn, but it glows with intense heat, and sends forth a light of almost overpowering splendor.

These are pretty experiments, and in many ways instructive. But for our present purpose I would ask you to fix your attention on one point only: that all the heat and light, produced in the flame of our lamp, is due to the clashing together of the hydrogen and oxygen atoms, under the force of chemical attraction. Now they never could have clashed together, unless they had first been pulled asunder. And therefore, in pulling them asunder, we gave them the capacity of producing that heat and light.

This is the sense in which the energy of heat may be said to be stored up in these two bags of oxygen and hydrogen. In the same sense it is also true that the energy of heat is stored up in a piece of coal. And, in a similar sense, as we have seen, there is a store of mechanical energy in an uplifted weight, in a running stream, in a stretched cross-bow, in a cannon ball shooting through the air.

**Storing of Electrical Energy not a New Idea.**—Having now before us, as I trust, a clear conception of what is meant by the storing of mechanical energy, and the storing of heat energy, we may pass on to the subject of more immediate interest, the storing of electrical energy. It will, perhaps, be a surprise to some of you, to hear that the storing of electrical energy is not a new idea, but one that has

long been familiar to the minds of scientific men. When a common electric machine is put in action, electrical energy is stored for a short time in the prime conductor, and is given out whenever a spark passes. It is stored, too, and more effectively, in a Leyden jar, when the Leyden jar is charged from the machine. And Nature, I need hardly tell you, has a way of her own for storing electrical energy in a thunder cloud.

Again, it may be said, with perfect truth, that every voltaic battery is a store of electrical energy. In a voltaic battery, some metal is employed, generally zinc, which, when the battery is working, is acted on chemically by an acid. The effect of this chemical action is that the atoms of the metal combine with the oxygen of the acid; and by the act of combination an electric current is generated. Now observe how closely this process resembles the process by which heat is developed from coal. In the case of coal, we have carbon and hydrogen existing apart from oxygen, with a chemical force tending to make them combine, under suitable conditions. We set up these conditions when we light a fire: the chemical force then comes into action; the carbon and hydrogen rush to meet the oxygen; and in the clash of atoms heat is developed. Similarly, in the voltaic battery, we have zinc existing apart from oxygen, with a chemical force tending to pull them together. We bring this force into action when we arrange the cells of our battery, and make the necessary connections; the atoms of zinc and oxygen then clash together, and, by the energy of their collision, an electric current is generated.

Thus it is clear that, exactly in the same sense in which heat energy is said to be stored in a lump of coal, it may also be said that electrical energy is stored in the zinc plates of a battery. It is worth observing, too, that both cases furnish a striking illustration of a universal law of Nature. We cannot use our store of energy, and keep our store, at the same time. We cannot get heat from coal, except by a process in which the coal is burned, and ceases to exist as coal. And so, too, we cannot get an electric current from our zinc plates, except by a process in which the zinc is gradually consumed, and ceases to exist as zinc.

But you will ask me, If every voltaic battery is practically a store of electrical energy, how is it that the discovery of a means of storing electrical energy has caused so great a sensation within the last twelve months? Is it to be said that we are able to do no more, with the aid of this new discovery, than we were able to do without it? I have led up to this question, because I want you to understand what it is precisely that this new discovery promises to do for us.

First, then, let me tell you that, although an ordinary voltaic battery is a store of electrical energy, it is an expensive store. To get an electric current from the battery we must, as I have just told you, consume the zinc plates, and zinc is an expensive metal. Speaking roughly, I may

say that it costs about twenty times as much as coal, weight for weight. Again, the arrangements that must be made, in order to get an electric current from the zinc, involve the use of other costly materials, such as nitric acid and sulphuric acid; they also involve the constant attendance of skilled hands. Hence it was found out, long ago, that the voltaic battery, however useful it may be in a scientific laboratory, or on certain special occasions, when cost is a matter of little moment, cannot be employed with advantage to supply electricity, on a large scale, for public use.

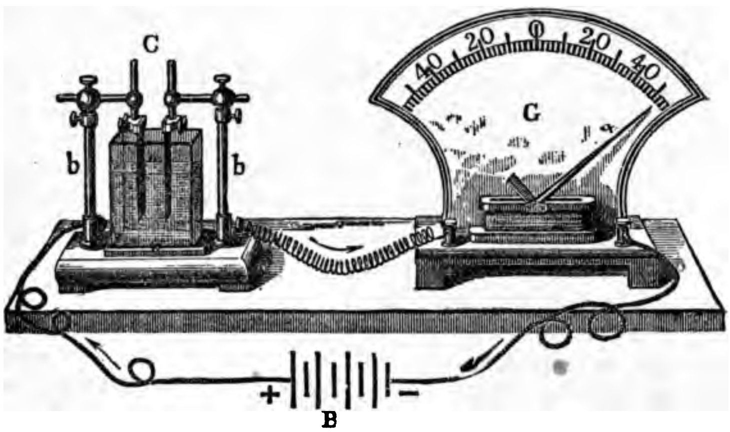
**The Storage Battery.**—Now the new discovery—the storage battery, as it has been very naturally called—differs from the ordinary voltaic battery in this, that it does not, of itself, give us an electric current, but it gives us a means of storing the energy of an electric current obtained from some other source. Thus you see, at once, that it would be of no practical use unless we had at hand some cheap and convenient way of producing electricity. But this want has been most opportunely supplied within the last few years. The dynamo-electric machines, which have now been brought to so high a degree of perfection, place at our disposal a supply of electricity which is at once very cheap, and practically unlimited in amount. In fact, it is the rapid and extraordinary development of these machines that has brought into such prominence, at the present moment, the question of using electricity as one of the ordinary agents of light and power.

This question, I need hardly say, is surrounded by many difficulties, some of which have been partially overcome, and some have yet to be encountered. But it is agreed, on all hands, that few difficulties would remain unconquered, if, having got a cheap supply of electrical energy, we could now cheaply store it up, in a convenient form, and keep it ready for use, as occasion might require. This is a problem eminently attractive to the man of science, and not less attractive to the practical man of business; and it is because the new storage battery seems to give fair promise of solving it, that it has created so great a sensation, and awakened so wide an interest.

The object of this battery is simply to make an electric current store up its own energy, in a form suitable for future use; and I will now try to give you some idea of the way in which this object is attained. We have already seen that when a current of electricity, coming from a voltaic battery, or from any other source, passes between two metal plates immersed in acidulated water, the water is decomposed by the action of the current, oxygen being set free at the surface of one plate, and hydrogen at the surface of the other. As a result of this decomposition, a new force is set up within the liquid, which opposes the passage of the current, and tends to produce a current of its own, flowing in the opposite direction. If now the battery current is cut off, and the two metal plates are connected by a wire,

outside the liquid, this new current will begin to flow, and to produce electrical phenomena in the circuit thus formed. The electric current obtained in this way is called a secondary current, to distinguish it from the current coming from without, which is called the primary current.

**Experiment to show Secondary Current.**—I should like to demonstrate to you by experiment the existence of this secondary




DECOMPOSITION CELL: PRIMARY CURRENT FLOWING.

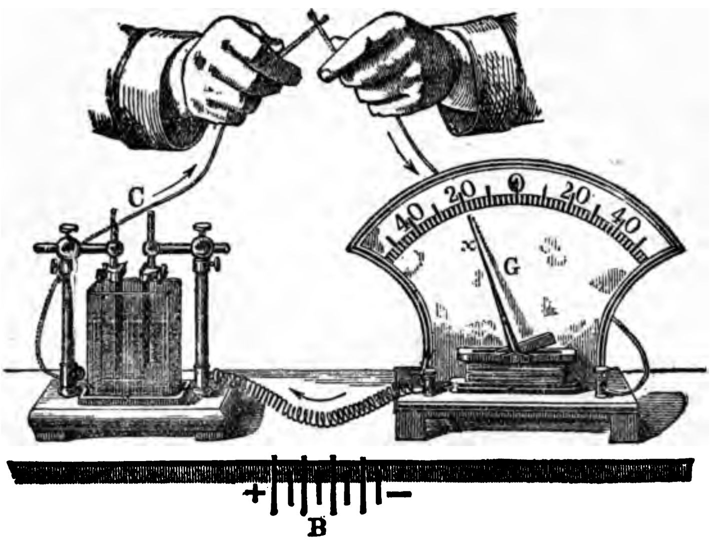
C Decomposition Cell.
*b b* Brass Pillars.
G Galvanometer.
B Battery.
*x* Index of Galvanometer, deflected to the right.

current. Here is a glass cell containing acidulated water. Plunged in the water you can see two metal plates: one is connected, by this brass pillar and a flexible wire, with the positive pole of a battery; the other is connected, by a second brass pillar and another wire, with one of the binding screws of a lecture-table galvanometer; and the second binding screw of the galvanometer is conected with the negative pole of the battery. By this arrangement the current from the battery is made to pass first through the acidulated water in the glass cell, and then through the galvanometer. When I put the battery in action, observe how the index of the galvanometer is at once deflected, showing that the current is passing. At the same moment bubbles of gas begin to appear in the glass cell, showing that the process of decomposition is going on. After the lapse of a few seconds, I break the circuit, and cut off the battery current. The bubbles of gas are no longer developed, and the index of the galvanometer returns to zero.

Let us now try if the glass cell, with its metal plates, can give us a current of its own. For this purpose I will take the wire coming from the first metal plate, and bring it into contact with the wire attached to the second binding screw of the galvanometer. The circuit will then be the same as it was in the first part of our experiment, with this difference only, that the battery is left out. When I make contact, mark how the index of the galvanometer is deflected, proving

that a current has begun to pass; and observe, too, that it is deflected not to your right, as it was before, but to your left, showing that the direction of the current, from the cell, is opposite to that of the current which came from the battery.

Now I want you to see clearly, before we proceed further, that this is a case of energy stored up. The energy of the primary current was first expended in doing a certain work, that is, in decomposing the molecules of water. As a direct consequence of this work, we had oxygen and hydrogen existing apart, with a chemical force acting between them, and tending to pull them together. This was our store of energy; and we drew upon the store when we cut off the




SAME CELL: SECONDARY CURRENT FLOWING.

C Decomposition Cell.
G Galvanometer.
x Index of Galvanometer, deflected to the left.

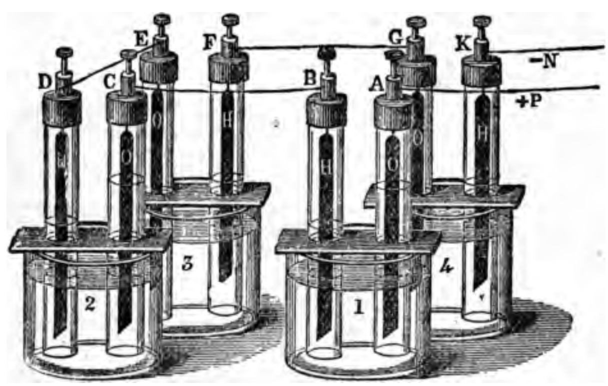
battery, and completed the circuit between the two plates of the decomposition cell. The chemical force was thus brought into action, the oxygen and hydrogen began to combine again within the cell, and in the act of combining they yielded an electric current.

I have dwelt at some length on this simple and familiar experiment, because it exhibits in a very clear light the fundamental principle of storage batteries. Some chemical change is produced within the storage cell, by means of a current of electricity which is made to flow through it; and in virtue of this change, the cell has a store of energy which it is ready to yield up, under suitable circumstances, in the form of an electric current. It remains for me now to describe briefly the principal attempts that have been made to apply this principle to practical purposes.

**Ritter's Secondary Pile.**—The earliest form of storage battery

was made just eighty years ago, in Germany, by Ritter, of Jena. He took two small circular discs of copper, and between them he placed a similar disc of cloth, steeped in acidulated water This combination constituted one element of his battery. He made a second element of the same kind, and laid it down on the first; a third, and placed it on the second; and so on, until he had built up a pile, or column, consisting of fifty or sixty elements. He now sent an electric current through the pile, from top to bottom; the water in the discs of cloth was decomposed, a counter electro-motive force was set up in each element, and when the battery was cut off, the pile yielded, for a short time, an electric current of considerable power. This battery is known as Ritter's Secondary Pile; but as the current lasts only for a few minutes, it is of little practical use.

**Grove's Gas Battery.**—Forty years passed away, and Ritter's secondary pile was almost forgotten, when a new form of secondary battery was devised by Sir William Grove, who was, at the time, Professor of Experimental Philosophy in the London Institution, and is now one of the Judges in the High Court of Justice in England. His plan was to combine together a series of decomposition cells, such as




GROVE'S GAS BATTERY.

1, 2, 3, 4, Cells of the Battery.
A B, C D, E F, G K, Glass Tubes closed at the Top, and filled with acidulated Water.
P Wire by which the Charging Current enters the Battery.
N Wire by which the Charging Current leaves the Battery.
O Strips of Platinum Foil at which Oxygen is set free.
H Strips of Platinum Foil at which Hydrogen is set free.

the one with which we have just been making our experiments. Into each cell he introduced two glass tubes, closed at the top, and filled with acidulated water. Every tube contained a long strip of platinum foil; and when the primary current was sent through the series of cells, it entered each cell by one platinum plate, and passed out by the other.

An arrangement of this kind, consisting of four cells, is on the table here before you; and you will observe that now, when I send the

primary current through, crowds of little bubbles appear in every tube, while the galvanometer, which is also in circuit, indicates by its deflection that a strong current is passing. After a little time, those who are near can see that, in each cell, oxygen is gradually accumulating in one tube, and hydrogen in the other. And now I cut off the battery current, and complete the circuit of our four cells. The secondary current at once makes itself manifest, and the deflection of the galvanometer indicates that the direction of the current is contrary to that in which the primary current had previously passed.

**Plante's Experiments.**—This combination of secondary cells is called Grove's Gas Battery. It has always been an object of great interest to scientific men; but for reasons on which I need not dwell, the current which it produces is extremely feeble, and quite unsuited for practical work. Eighteen years more passed by, and the secondary battery still remained in the obscurity of the scientific laboratory, when, in the year 1860, Monsieur Gaston Planté exhibited his now famous cell before the Acadamy of Sciences in Paris. I think it should always be distinctly recognized that Gaston Planté is the man to whose patient and laborious researches we are mainly indebted for the position which the secondary battery occupies, at the present moment, in the eyes of the world.

These researches were begun in the year 1859, and have been continued, I may say, down to the present day. His first object was to discover what metal was the best fitted for storing up electrical energy in a decomposition cell. After a long series of experiments, in which he tried gold, silver, platinum, copper, and other metals, he finally satisfied himself that lead was the best suited for the object he had in view. In the case of most other metals, the oxygen and hydrogen, produced by the decomposition of water, exist only as little bubbles of gas clinging to the surface of the plates at which they are evolved. But in the case of lead, these gases effect a chemical change, which gives to the plates a new character, of a more of less permanent kind; and this new character constitutes, in effect, the store from which the secondary current is derived.

Further, Monsieur Planté discovered that it is possible to increase very much the natural capacity of lead plates for storing electrical energy, by putting them though a process which he called the *formation* of the plates. This process, which extends over a period of three or four months, is much too tedious and complicated to be described in detail on an occasion like the present. But I may say, generally, that it consists in sending a current of electricity through the cell, first in one direction and then in the other, several times in succession, with intervals of rest between; and that the final result is to produce on one plate a substantial layer of lead peroxide, and to reduce the surface of the other plate to the condition of spongy or finely divided metalic lead.

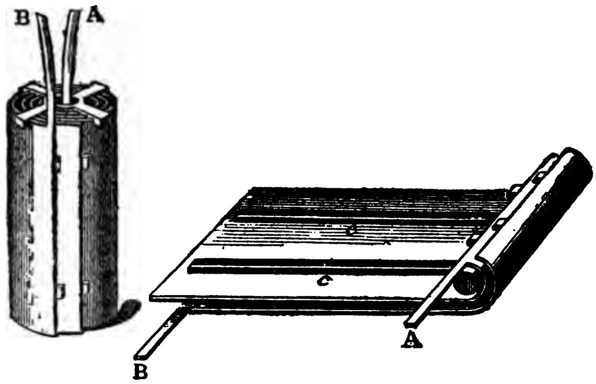
Here are two lead plates, which have been prepared in the manner described; and I will now show you that they contain a store of electrical energy, on which we may draw at pleasure. I plunge them, at a short distance apart, in a glass containing acidulated water; and then I connect them externally by a wire, including, as usual, the galvanometer in the circuit. The index of the galvanometer is immediately deflected to the extreme end of the scale, showing that a strong and steady current is going out from the cell. So long as the two plates retain their distinctive characteristics, so long will the current continue to flow. But, remember, we cannot use our store and keep our store at the same time. As the current continues to flow, oxygen is taken away from the layer of lead peroxide, and deposited on the layer of pure spongy lead; the peculiar character of each plate is thus gradually effaced; the store of energy becomes, in course of time, exhausted; and the current ceases to pass.

The capacity of such a cell as this, for storing electrical energy, increases as the surface of the metal plates is increased. It was, therefore, an object with Monsieur Planté, in the construction of his cell, to have the largest possible surface of lead in a convenient and portable form. To attain this end, he took two plates of lead, about ten inches in breadth, and from twenty to thirty inches in length. These he laid one over the other, separating them by narrow strips of india-rubber; then he rolled them up tightly together in the form of a scroll, and plunged the whole mass endwise into a cylindrical glass jar, containing dilute sulphuric acid. Next followed the process of *formation*, as already described, and the cell was then ready for use. I have here a Planté cell, which, as you see, is about one foot high and four inches in diameter. It was charged a few days ago, and when I now complete the circuit, the current is powerful enough to raise this spiral of platinum wire to incandescence, and produce a brilliant white light.

**Faure's Improvement.**—The Planté secondary cell has long been used, with advantage, to store electrical energy for small surgical operations; it has been used also, to some extent, for the production of the electric light. But the *formation* of the plates is a process so tedious and costly that this form of cell, on a large scale, is not likely, I think, to come into general use. Hence a lively interest was awakened, last year, when it was announced that Monsieur Faure, of Paris, had invented a new secondary battery, in which there was no need of such a process.

The plan adopted by Monsieur Faure may be explained in a few words. He first covers over the surface of the two lead plates with a thick layer of red oxide of lead; then he immerses them in a cell containing dilute sulphuric acid, and sends an electric current through the cell from plate to plate. The effect of the current is, practically,

to deposit oxygen on the plate at which the current passes in, and to abstract it from the plate at which the current passes out; thus raising the layer of red oxide, on the one plate, to the condition of lead




THE LEAD PLATES OF THE PLANTÉ CELL.
On the right, the Plates are seen opened out; on the left, they are seen rolled up.

A B Strips of Lead, one projecting from each Plate. | *c c* Strips of India-rubber to insulate the Plates.

peroxide, and reducing it, on the other, to the state of pure metallic lead. This change is accomplished in one or two days; and when it is complete, the cell has got its charge. It will keep this charge stored up, with very little loss, for a period of several days, or it will give it

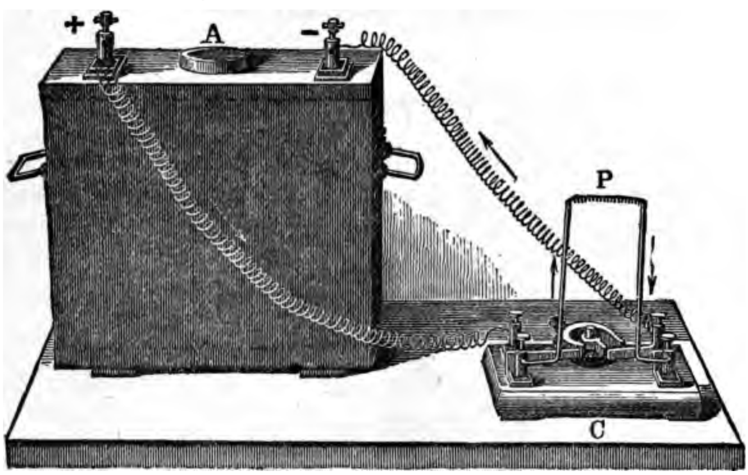

THE PLANTÉ CELL COMPLETE.

A Strip of Lead by which the Charging Current enters the Cell. | B Strip of Lead by which the Charging Current leaves the Cell.

out, at our pleasure, whenever it is wanted for use.

In practice Faure uses for his cell a rectangular box, which holds ten or twelve plates. Each plate is covered over tightly with felt to

prevent the paste of red oxide from falling off, and the plates are so connected together that they act as two single plates, of very large surface. The amount of electrical energy that can be stored in one of these cells may be expressed in terms of mechanical energy; and it has been determined, by accurate measurement, that a cell, weighing somewhat less than a hundred pounds, can store a million foot-pounds of energy, which is equal to one horse-power working for about thirty minutes. Such a cell as this, fully charged, is here on the table before you, and fairly represents the "marvellous box of electricity" which appeared in England, for the first time, last summer, and of which so much has been written and spoken during the past twelve months. The wires coming from the two poles of the cell are connected, as you see, with the binding screws of this commutator; and when I turn the




THE FAURE CELL IN ITS EARLIEST FORM.

A The Cell; A Wooden Box, with a Hole in the Top, closed with a Bung, for introducing the Acid.
C The Commutator.
P Platinum Spiral.

handle of the commutator, a current of electricity flows through a spiral of thick platinum wire, producing intense heat, which makes the wire glow.

**What a Storage Battery can do.**—You will have no difficulty now, I think, in understanding what a storage battery is, and what it is able to do. It is simply a number of these cells—twenty, thirty, or a hundred—ranged side by side, combining their forces together, and ready, at the turn of a handle, to pour forth a powerful stream of electricity, which we may use at pleasure, either to illuminate our houses or to drive our machinery. A small battery of this kind is set up here on the table beside me. At present the current is not flowing, and the energy of the battery remains stored up. But I now complete the external circuit by turning the handle of this little com-

mutator. In a moment half a dozen incandescent lamps scattered over the table are all aglow, shining with a brilliant white light.

At a little distance, on another table, are four more lamps which are still dark. I turn another handle, and they too begin to glow, while the first continue to shine as brightly as before. On the floor, at my left, is a circular saw, provided with an electro-motor to drive it. I turn a third handle, which brings the electro-motor into the circuit of our battery; the saw is driven rapidly round, and cuts right through a stout piece of timber which my assistant presses against it. By reversing the motion I can, of course, stop the machinery, or put out the lamps, just as I please: or I can shut off the current altogether, and the energy that remains will continue stored up in the battery, until it is again wanted for use.

But some one, perhaps, may be disposed to ask, What, after all, can be the use of a storage battery, if, as I have told you, we can get no electrical energy out of it except what we first put in? Is it not a new element of expense, interposed between the manufacture of an electric current and the consumption of it? I answer, it is useful because it is convenient. It promises to do for electricity what a gasholder does for gas: to store it up according as it is made, and to give it out according as it is wanted. Further, I say it is useful, because it puts it in our power to turn to useful account a vast supply of energy which is now simply going to waste. What the mill-pond does, on a small scale, for the miller, the storage battery promises to do for the whole population, on a scale of great magnitude: to catch the energy of the flowing stream, which is now running idly by, almost at our very doors, and to lay it up, in a convenient form, until we are ready to use it.

**Practical Illustrations.**—If I have not already trespassed too far on your patience, I should like to touch briefly on one or two illustrations of this interesting and practical question. Suppose you want to light your house with those beautiful incandescent lamps of which I have shown you some specimens here to-day, you have only to get a storage battery, proportioned in size to the illumination you require, and stow it away in a convenient corner of your basement floor. A wire is laid on to your house from a central station, your battery is charged every morning with a store of electrical energy, and you can draw on that store, to illuminate your house, just when you please, and how you please.

I may mention, in passing, that Mr. Edison has just invented a very simple apparatus to measure the amount of current that comes into your house: thus you will only have to pay for what you get. And Sir William Thomson has invented an apparatus which, of itself, will cut off the current as soon as your battery is fully charged: thus you will only get what you want, and none will go to waste. It may

be observed, too, that if you desire a more than usually brilliant illumination, for some festive occasion, you have but to order a few extra cells and hire a few extra lamps.

Again, let me take the case of a small country town, with a waterfall near at hand, or a strong flowing stream. The energy of the falling water can be converted into an electric current, at hardly any cost, by means of dynamo-electric machines. Then, if a large storage battery is provided for the illumination of the streets, and if each house has its own small battery for private use, the energy of the stream during the whole period of twenty-four hours can be stored up to light the town during the hours of darkness. A greater store of electrical energy will be wanted, of course, in winter than in summer, as the period of darkness is longer; but Nature happily provides for this increased demand by giving us, in winter, a stronger flow of falling water.

**The Storage Battery as a Motive Power.**—As a motive power, these storage batteries seem eminently fitted for driving tram-cars. An ordinary tram-car, with its full complement of passengers, weighs about four tons. To drive this weight, at the rate of six miles an hour, we should require an electro-motor working at about three or four horse-power on the level road, but capable of working up to eight or ten horse-power, in going over bridges and up steep inclines. Now, from the experience we already possess, I think I am safe in saying that the electrical energy required to work such a motor continuously, for two hours, can be stored up in boxes that would fit conveniently under the seats of the car. If this be so, then it would only be necessary to provide a large supply of these storage batteries at one end of the line; to set up a couple of steam engines which could be kept constantly at work, charging the batteries; and we might get rid, at once, of a whole troop of horses, with all their attendant expenses.

In the application of storage batteries to the driving of tram-cars, there is one point of especial interest on which I would dwell for a moment. Every one must have observed what a great waste of energy takes place every time a tram-car is stopped on its journey. Moving at the rate of six miles an hour, it possesses, within itself, a very considerable store of energy, and before it can be pulled up all that energy must be destroyed. If it is destroyed by means of a brake, it is simply wasted; if it is destroyed by the aid of the horses, as often happens, then not only is it wasted, but fresh energy is expended in wasting it; and when the tram-car is again started, the horses are called on for a new effort to develop once more the energy which has just been destroyed. Hence it has long been a project with mechanical engineers to devise some means of storing up the energy with which the tram-car is moving before it is stopped, and to use that store for starting it again. Up to the present time this project has been little

more than a dream, but it would seem that these storage batteries now enable us to make it a reality.

When the battery is driving the tram-car, a current of electricity flows from the battery into the electro-motor, causing the bobbin of the electro-motor to rotate on its axis, and thus driving round the wheels of the tram-car, which are connected with the bobbin. But it is quite possible, by the mere turn of a handle, so to alter the relation between the electro-motive force of the battery and that of the motor, that this process shall be exactly reversed. The revolving wheels of the tram-car will then drive the bobbin round, thus generating an electric current, which will flow back into the cells, and charge the battery. The moment this change is made, the moving tram-car not only ceases to receive any further impulse from the battery, but it is called upon to do work, in generating an electric current. In doing this work it rapidly expends its store of energy, and soon comes to a standstill. But the energy thus expended is not wasted; it is added to the store of energy already existing in the battery; and when the handle is turned back to its former position, it will help to start the tram-car again.

From tram-cars it is not a very violent transition to private carriages. No doubt, so long as our streets remain in their present condition, we must be content to jog along in the jolting and jarring fashion to which we are accustomed. But if I might fancy a time when our rugged pavement had given way to a smooth and pleasant flooring of asphalte, I see no reason why a box of these cells might not take the place of horses in carriages and other vehicles. On such a roadway one horse power would be amply sufficient to drive a fair-sized carriage, as fast as it would be safe to go through the streets of a crowded city; and a moderate-sized battery, which might be stowed away in a convenient recess of the carriage, could store up energy enough to yield the work of one horse for a drive of two or three hours.

**The Storage Battery on its Trial.**—And now, in coming to an end, I should wish to remind you of what I said in setting out, that the practical value of this storage battery can be fully determined only by actual trial. At the present moment, it seems to me somewhat in the condition of a hot-house plant; which blooms and flourishes so long as it is confined to the artificial atmosphere in which it has been nurtured, but which, when transferred to the open air of our gardens, is found, very often, unable to bear the rough winds and the changeful climate of a ruder life. This secondary battery has hitherto been carefully and tenderly cherished, under the artificial conditions of the scientific laboratory; and under these conditions it has shown quite a wonderful and vigorous development. The time is now come when it will be called upon to encounter the rough usage and, so to say, the wear and tear of a working life. If, like a hardy plant, it is able to accommodate itself to these new conditions, and continues still to flourish and

to develop fresh growth, then there is not one of the speculations I have set forth which may not be realized, even in our own day. But if it should break down under the trial that awaits it, and if our speculations should come to nought, nevertheless the great principles on which I have been insisting—which rest on the solid foundations of science, and which we have found so beautifully illustrated by the secondary battery—these principles will still survive, and the time we have spent in discussing them will not, I trust, have been spent in vain.

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## On the Recent Progress and Development of the Storage Battery.

Soon after the date of the above Lecture, the storage battery began gradually to come into use, for practical purposes. In many respects it amply fulfilled the hopes awakened by its first discovery. But, as in the case of most other inventions, when it was put to actual trial, some unexpected difficulties presented themselves.

**Modifications of the Faure Cell.**—In the first place, it was found that, after the Faure Cell had been a little time in use, the current leaked across from one plate to the other, through the flannel, or felt, by which they were separated; and of course the current, in so far as it thus leaked from plate to plate, was practically wasted, and ceased to be available for useful work. To meet this inconvenience, the felt was got rid of, and the plates were kept in position by short studs of ebonite, or india-rubber, fixed between them. An incidental advantage of this change was that the internal resistance of the cell was reduced: a matter of great importance in connection with Electric Lighting.

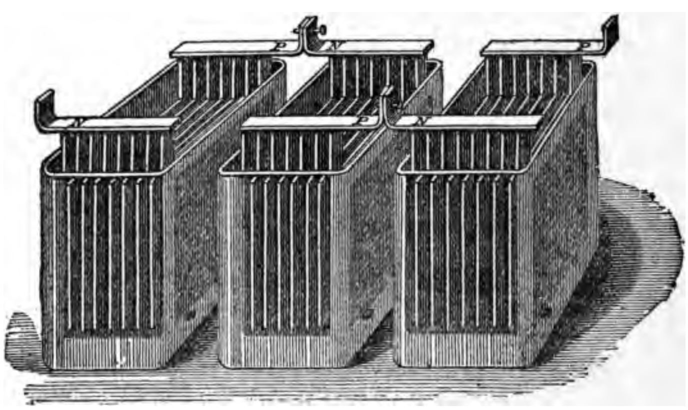
It became, however, necessary to devise some means by which the paste of lead oxide might be made to adhere firmly to the plates, when deprived of the support which it had previously received from the felt. This has been effected by a new method of preparing the lead plates. Before the paste is put on, every plate is honeycombed on each surface with an immense number of quadrangular indentations, or cells, sinking some distance into the thickness of the plate. The paste of lead oxide is then pressed into these cells, and when it dries it holds a firm grip of the plate, and presents a uniform surface to the action of the acid.

It may be well, perhaps, to say that the plates are now made, not of pure lead, as formerly, but of an alloy, which is harder than lead and stands the work better. The paste, too, which is used to cover the plates is not exactly the same for the two plates of each cell. The positive plate, that is, the plate at which the current enters when the

cell is being charged, is covered with a paste of red lead ($Pb_3 O_4$), and the negative plate with a paste of Litharge, or lead monoxide ($Pb O$). In both cases the oxide is largely converted into sulphate of lead, in the process by which it is prepared; and then, in the charging of the cell, the sulphate of lead is changed into peroxide of lead ($Pb O_2$), on the positive plate, and reduced to the condition of spongy lead on the negative plate.

**Difficulty of maintaining Insulation of the Plates.**—But even this improved form of cell is not without its faults. It is found that the lead peroxide, however firmly it may be set in the first instance, has a tendency to come off in scales, which fall down to the bottom of the cell. Hence if the lead plates rested on the bottom, a conducting layer of peroxide would, sooner or later, be formed between them, and the insulation of the plates thereby destroyed. This danger has been successfully obviated, by not allowing the plates to rest on the bottom of the cell, but supporting them on ridges of ebonite, or glass, or other insulating material.

Sometimes, however, it will happen that the scales of peroxide, in falling down, get caught between the two plates, and thus form a bridge, which practically destroys the insulation of the plates. There is no way yet known of preventing this evil: but it may be remedied, when it arises, by passing a thin lath of wood, or ebonite, or some such material, between the plates, and setting free the scales of peroxide, which will then fall to the bottom.



THREE STORAGE CELLS OF THE MOST IMPROVED FORM.

**Newest Form of Cell.**—To facilitate this operation, the plates are now generally placed in glass cells, instead of wooden boxes; and thus the condition of the plates can be conveniently examined, from time to time, without disturbing them. The adjoining figure, which represents three cells of the Electric Power Storage Company, will give a good idea of the Storge Cells, in their most improved form. It will be

observed that each negative plate, marked N, consists of eight separate plates, joined together, at one end, by a thick strip of lead; and that each positive plate, marked P, consists of seven separate plates, similarly joined. Moreover, the negative plate of one cell is connected with the positive plate of the next: this arrangement is known as "arrangement in series," and is the one most commonly used for practical work.

**Buckling of the Plates.**—Perhaps the most serious difficulty encountered in the use of Storage Batteries is that, when a cell has been in use for some time, the positive plate shows a tendency to bend, or "buckle," as it is called; and, in this way, it comes into actual contact with the negative plate, thus forming a short circuit through which the cell is discharged. This evil, which is fatal to the usefulness of a cell, is said to be hastened if the Battery is too rapidly charged, or too rapidly discharged, or if the charge is reduced too low, or if the Battery is left too long uncharged. But, even with the greatest care, the evil cannot be altogether prevented; and, after lengthened use, the positive plates will buckle and become useless. How far this fault will eventually interfere with the practical utility of the Storage Battery, it remains for future experience to determine.*

**Available Energy of a Cell.**—There is one respect in which the anticipations, expressed in my Lecture, have not yet been fully realized by experience. In the early days of Accumulators, it was usual to speak of each cell as containing so many foot-pounds of energy; and it was tacitly assumed that this energy was available in whatever way we might please to use it. Thus, for example, a million foot pounds of energy is equivalent to half a horse-power for an hour; and it was assumed that, if we had two cells, each containing a million foot-pounds of energy, we had practically at our disposal one horse-power for an hour.

But this assumption was soon proved to be inadmissible in practice; First, it was found that we cannot drain off all the energy stored up in a cell, without doing serious injury to the plates. If we wish to keep our Battery in good condition, we must take care only to draw off a certain portion—not more than two-thirds—of the energy it contains. It is usual now to speak of this available portion as the *useful* energy of a cell; and in all practical calculations we should take into account, not the total energy stored up, but only the useful energy.

Again, even as regards the useful energy, we are not at liberty to draw it off at any rate we please. We have learned from experience that, for every storage cell, according to its size, there is a certain maximum rate, at which the energy may be drawn off, in the form of an

*It is right to notice here that the Electric Power Storage Company have, quite recently, brought out a new type of cell, in which, they say, "the plates are so arranged that there is no possibility of internal short circuits caused by the lodgment of plates or pellets of oxide, or powdered paste, at the bottom of the cells;" and for which they further claim that "internal short-circuiting [illegible] possible," If we may accept these statements literally, and if they be verified when the cell [illegible] subjected to a sufficiently long trial, it would seem that the difficulties described in the [illegible] been, at length, completely overcome.

electric current, without injury to the plates; but if this rate is exceeded, the plates will soon begin to buckle. Thus, for example, in a particular form of cell now made, the useful energy stored up is equivalent to one horse-power, for an hour: but we cannot use it *at the rate* of one-horse power, and draw it all off in an hour, without seriously damaging the plates; we can use it at the rate only of one-tenth of a horse-power, drawing it off in ten hours.

These principles, which were not so clearly understood at the date of my Lecture, create some difficulty, no doubt, in the application of storage cells to the driving of tramcars and other vehicles. In the case of a tramcar, for instance, if we want ten horse-power for an hour, to run a double trip of three miles each way, it is not enough to provide cells with that amount of energy stored up; we must take care first, that the amount of *useful* energy stored up is equal to ten horse-power for an hour, and secondly, that it may be drawn off *at the rate* of ten horse-power, without injury to the plates.

But notwithstanding this difficulty, there seems to be little doubt that, in a few years, storage cells will be very generally employed at the motive power on tramway lines. Already, on the Continent of Europe, tramcars are driven by Accumulators in Brussels, in Hamburg, and in Cologne. Even in England, which is rather behind hand, as compared with other countries, in the practical applications of electricity, there are two lines of tramway worked by Accumulators, one in London, and one in Brighton, each about four miles in length.*

**Storage Battery for Electric Lighting.**—As regards Electric Lighting, the Storage Battery, in its improved form, is now largely used, with great advantage, in the case of small installations. The Battery is placed in the basement story of a house, or in an out-office, and is charged at any convenient time, once or twice, or oftener, in the week, by means of a dynamo, worked by a gas-engine, or a steam-engine, or by water power; and then the lamps may be turned on, at any hour of the night or day, according as they are required. Such a Battery is, no doubt, an expensive element in an Electric Light installation. But it has two great advantages: first, it gives a perfectly steady current, and, therefore, a perfectly steady light; and, secondly, it may be charged at whatever time may be found most convenient, and used whenever it is wanted. I would go so far as to say that, for a small Electric Light installation, especially in a private house, a Storage Battery is not only useful, but practically indispensable.

The case is different, however, when we come to deal with a central station, designed to send out currents for a house-to-house illumination, over a given area. It is sometimes said that great Storage Batteries would be just as necessary, at such a central station, as great gas-holders now are at a central gas station. I am not inclined to take

*See The Electrician, May 25, 1888. page 84.

this view of the question. If it should be found necessary to store the electrical energy generated at a central station, I think it can be stored more economically at the houses of the consumers, than at the central station itself. For this purpose, it would only be necessary that each house should be provided with a Storage Battery, suitable to its wants; and the Battery could be charged by a current from the central station, whenever required.

But it is by no means certain that a Storage Battery will be found, eventually, a necessary element in the distribution of electric currents, from a central station. Several attempts have already been made, with more or less success, to carry out such a distribution, on a small scale; and in these attempts, so far as I know, the Storage Battery has not been employed. The problem of a house-to-house illumination, on a large scale, has only been taken in hand quite recently; and we have yet to learn from practical experience, the only certain guide in such a matter, in what way it can be carried out, at once most efficiently and most economically.

THE END.

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